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An All Out Entomological Program

Presidential Address Fifty-Sixth Annual Meeting, American Association of Economic Entomologists

E. O. ESSIG, *University of California, Berkeley*

It should be a matter of some rejoicing, I feel, that we are able to gather again in the annual meeting of these great organizations of entomologists. In spite of the difficulties and discomforts of civilian travel during these trying times, in spite of the busy days that have been all too short to permit the completion of the many tasks that may still remain unfinished, in spite of the fears that we may hold as to the lack of importance of our own part in winning the war, we are here and it is now our duty to do everything possible to make these meetings fruitful and successful to the highest degree.

There should be no doubt in our minds as to the great value of entomology as a science essential to the winning of the war. The important role of insects in the fields of medicine, sanitation, and agriculture, is paramount and the recruiting of so many of our members to serve the armed forces is abundant evidence of this fact. The defense of agriculture at home is an indispensable obligation which we should develop and perfect to the very best of our united abilities and experiences. To this end let not a single one of us be found wanting. Those of us who have been looking forward to these meetings as necessary to the winning of the war, will find the time only too short to accomplish all that has been planned and therefore we should take heed to everything that is said and done that will add to our individual efficiency and to the benefit of our communities and our country.

There are so many important matters to be considered that have to do with the present and even more pressing things that concern the future, that I have found it difficult to choose wisely for presenting to you just those things that may count for the most right now and for those not too far distant days when we shall need to eliminate existing disorders and deficiencies and replace them by new and more adequate and permanent programs.

This address is intended to be a review of some of the problems that face us now and are likely to become even more important during the immediate future and the postwar period. In certain cases, a solution may be suggested and in other instances I am hoping that others in our Association may name a remedy. But in all cases I trust that what I may say is to be taken only as introductory remarks with the thought that this presentation will call forth interest and action on the part of our membership. Too often we all recognize serious difficulties and defects in our programs of teaching, research, publication, and professional ethics, without taking the trouble to correct the abuses ourselves or to offer suggestions whereby others might make the necessary improvements. An organization or government can accomplish little real good for its constituents without the live interest and the constant support of its membership.

ENTOMOLOGICAL TRAINING.—Entomology is a relatively young science being little more than 100 years old, and for many years was a pastime of amateurs and a source of enjoyment and instruction to those interested in field biology and in making collections. Teaching did not really get under way until after the organization of the State Agricultural Experiment Stations provided by the Hatch Act of 1887. Among the earlier pioneer teachers were: H. A. Hagen, Harvard

College; S. A. Packard, Brown University; C. H. Fernald, Massachusetts State College; J. H. Comstock, Cornell University; Herbert Osborn, Ohio State University; C. W. Woodworth, University of Arkansas and University of California; F. H. Snow, University of Kansas; P. A. Garman, University of Kentucky; John B. Smith, Rutgers College; A. J. Cook, Michigan State College; Lawrence Bruner, University of Nebraska; C. P. Gillette, Colorado Agricultural College; and several others who might also be mentioned.

The teaching of entomology in our American colleges and universities was well founded and has through the years gradually assumed a personality all its own. The spirit and customs of the early founders and leaders still permeates to a considerable degree the classroom, laboratory, and field plot by those who were trained and inspired by these pioneer teachers and investigators. However, there have been powerful forces at work to change much that has been handed down to us. The great expansion of agriculture with more difficult problems in the claiming of vast areas of semi-arid lands; the greater specialization in growing old and new crops; the greater demands of fruit and vegetable standardization and pure food laws; the tremendous developments in the discovery, manufacture, and supply of new and ever newer and more exacting and more efficient insecticides; the imposition of insecticide tolerances; plant quarantine laws and regulations; the application of statistical methods of research; and others. These more practical considerations have modified methods of teaching and curriculums very much and have often completely overshadowed and crowded out what are generally considered to be the more basic considerations of taxonomy, nomenclature, diagnosis, physiology, ecology, history, ethics, and other specialties. In addition, entomology in all of its various phases must be correlated with all of the other numerous fields of biological sciences as well as with chemistry, physics, medicine, engineering, geology, paleontology, anthropology, languages, literature, photography, printing, art, and many others.

We are therefore faced with the problems of preserving the old methods and continuously adding the new. It is not difficult to see that such a process cannot continue very many years without losing at one or at both ends. Naturally the trends are usually towards the new and modernistic viewpoints and we can expect no other result. Much of the old in form and methods have been dropped of necessity and who is to say not advantageously. What I hope we may keep is the general attitude, enthusiasm, and spirit of helpfulness of these older professors, and the subject matter from the past and the present.

It will always be necessary to emphasize basic training and I am sure you are all sufficiently familiar with the idea to make it unnecessary for me to elaborate on it. No institution can be strong in entomology that does not teach the fundamental principles of classification, anatomy, physiology, ecology, and diagnosis, and no institution can adequately teach these subjects unless its instructors are not only interested but actually doing research work in these basic fields.

Among the many requisites of an able and satisfactory teacher are two which seem to me to be paramount: Enthusiasm for his subject and a deep and lasting interest in his students.

If he is really enthusiastic about his profession a real teacher is almost sure to be much more than adequately prepared and abundantly qualified to train all who come under his tutelage. He is likely to invest a considerable amount of his income in books and reference literature, to secure adequate insect collections in his special fields, to acquire the necessary historical background, past and present, and to correlate his knowledge with, and to hitch his enthusiasm to, modern circumstances and problems.

A deep and lasting interest in his students is one of the very finest and most valuable qualities of a great teacher, because such a teacher is always conscious of his responsibilities to his students and of the great opportunities being afforded him to train them properly, not only in book learning, but in all the knowledge of life as acquired by his own experiences. The relationships between a University professor and his graduate students are not unlike that of father and son and many a professor has been able to do even more for a boy than has been possible by his own father. Through the years that

follow, such a teacher continues his interest in all his students: helps them to find worthy positions, encourages them, supplies needed information, and most of all is forever a true friend to whom they may come in person or by letter for help in all the multitudinous problems of professional, social, and private life. The fulfillment of such wonderful opportunities for serving the youth of our country is among the greatest accomplishments of American colleges and universities. In our contacts with students, other faculty men, and with the public, we should never lose sight of these responsibilities, as they may arise in all their varied and complicated forms.

EXCHANGE PROFESSORS.—Prior to the first World War in 1914, exchange professors were quite the rule among many universities and colleges in the United States. These exchanges served a very important purpose in leavening methods of teaching and in bringing entirely new ideas to most institutions concerned. They fostered good feeling among faculty members and students and often very greatly aided and stimulated research work in the laboratories and in the fields. Those who were so fortunate as to participate in the exchanges enjoyed not only the inspiration and opportunities of having personal contacts with entirely different staff members and students, but were greatly refreshed by their new surroundings and different climatic conditions.

Unfortunately, this practice has almost completely died out and no steps have been taken in recent years to reestablish it. I believe that we entomologists should endeavor to create a new interest in exchange professorships and suggest that a resolution be addressed to the Association of Land Grant Colleges and Experiment Stations calling attention to the importance of such exchanges and requesting their support in reestablishing exchanges among teachers and investigators in the institutions which they represent.

POSTWAR PLANNING—ADVANCEMENT FOR STAFF MEMBERS.—That there will be an unprecedented enrollment at all institutions of higher learning at the close of the war is an accepted fact and most universities and colleges are attempting to meet any emergencies and situations that may arise to the extent of gathering estimates of office, laboratory, and classroom space; assistants, equipment, supplies, and other necessities that may be required. State legislatures, in some cases, have already agreed to supply funds to meet these needs for education and training and large programs are already getting under way.

We as entomologists should be on the alert to see that our departments are adequately cared for in every respect. This may be the time to secure many of the things our various departments lack to make them outstanding leaders in entomology.

If the increased enrollments materialize, as is now believed, there will be great need of additional assistants and instructors. These conditions might set up just the right opportunities to enable those in charge to give due consideration for recognition and promotions to all those who have sacrificed so much during the past three years to serve their country. This service has been given as generously and with just as great love for country by those who have labored day and night without holidays or rest of any kind at home, as well as by those who have made greater risks of life in foreign fields. There will be new positions to fill and advancements to be made. These advantages should be reserved for those who have served with us before and during these trying times, rather than to be handed out to outsiders. We all have very real and serious responsibilities in connection with these postwar programs and not one of us can afford to take such matters without great mental and physical effort to make the most out of every item that will advance our work and our profession.

In many educational institutions the salaries are still far too small and out of all proportion with those in other professions in public service and in business. Industry is attracting many of the ablest teachers and investigators from our colleges, universities, and agricultural experiment stations and it will be necessary for these latter institutions to meet this competition not only by maintaining strict adherence to principles of academic freedom, but also by adopting a higher salary scale. We must constantly endeavor to bring about these necessary changes. At this particular time they are far more important and urgent than all of our curricular worries!

ASSOCIATION OF LAND GRANT COLLEGES AND EXPERIMENT STATIONS.—As has often been pointed out American Economic Entomology is more than anything else a product of the Agricultural Colleges and Experiment Stations. It was brought into being and has been continuously supported and developed by the latter and our future will be largely determined by the deans and directors of those colleges and stations. It has occurred to me that the entomologists might accomplish a great deal more in strengthening their departments and in acquiring many fundamental necessities such as representative insect collections, insectaries and greenhouses, adequate insect control equipment including spraying, dusting, and fumigating machinery, adequate entomological libraries, possible exchange of teachers and investigators, and other important advantages by working with and through such an organization as the Association of Land Grant Colleges and Experiment Stations. This organization has done much to further all the teaching, research, and extension work in relation to agriculture. Would it be worth while to contact the officers of this association to see how far we might be able to solicit their aid and cooperation in connection with the improvement of entomological teaching, investigational, and extension work throughout the country?

PUBLICATIONS.—One of the most important problems that faces the productive entomologist and especially those interested in the more systematic and biologic phases of the subject is publication. There has been a great deal written and said about this matter during the past ten years, but much more has been said than done. In fact very little has been done. One of the reasons for our present difficulties is the fact that some of our editors and business managers believe there is no real shortage of space in our entomological journals. So long as this feeling exists there will be no serious effort made to provide additional and new avenues for publication.

I think there are several outstanding needs in this field which should be considered in our present and also in our postwar planning. The greatest expansion should be to provide for systematic papers. There is hardly a systematist who enjoys the opportunities of having adequate space, proper illustrative material, and the type of articles, monographs, and series he would like to publish. Since authors freely contribute their manuscripts it would seem that the matter of publication and distribution should be provided for by organizations founded for such purposes and liberally supported by those who need such material. I believe that much more useful papers would be provided on practically every entomological subject if more support was available for thorough reviews, comprehensive monographs, illustrated keys, complete bibliographies, host indexes, distributional lists, insect surveys, etc.

Reviews. Up-to-date reviews in all fields of entomology are greatly needed to keep abreast with the very extensive literature and the ever changing conditions in classification, nomenclature, insecticides and their uses, in distribution, additional host plants and host animals, and similar subjects. It would require literally hundreds of such reviews to bring the important fields and subjects up to date and enable the average entomologist to acquire the important facts necessary about a given subject. A beginning has been made in certain fields of economic entomology and should be broadened to cover all fields. I heartily recommend that our Association broaden its scope of publication as rapidly as possible even to the extremity of charging extra for the reviews rather than to limit their number, scope, or value.

Monographs, illustrated keys, bibliographies, and host indexes are among the best reference tools a working entomologist can possess and we need these kept strictly up to date.

INSECT SURVEYS.—These are of special value. Every state should complete and publish such surveys just as soon as possible. Such lists as the Insects of New Jersey by John B. Smith, the Insects of Connecticut, by W. E. Britton and R. B. Friend, the Insects of New York, by M. D. Leonard, and the Insects of North Carolina, by C. S. Brimley are of inestimable value to every entomologist interested in either systematic or economic entomology.

The insect pest surveys conducted by the U. S. Bureau of Entomology and Plant Quarantine and by the Dominion of Canada, Department of Agriculture,

Division of Entomology have been a great aid to all entomologists and other biologists the world over and we are all greatly pleased to know that the survey of the former is to be continued and expanded as rapidly as possible.

RELATIONS WITH OTHER ORGANIZATIONS.—In spite of the many opinions to the contrary, the duplications in membership, the suggested savings, and greater unity, I am of the opinion that for the time being at least the Entomological Society of America and the American Association of Economic Entomologists can best function as separate organizations. Each of these groups has more or less separate and distinct functions to perform and what is even more important they serve as stimuli and contenders which condition is sure to react favorably on both. Then, too, the long fine cooperative spirit between these two organizations has created an *esprit de corps* in American Entomology that has done much to strengthen our profession among scientific organizations in America. We should strive to invigorate both of these groups and to continue to work together in harmony and good will.

As a means to further strengthening our Association, I should very much like to see the North Central States Group of Entomologists affiliated as a branch, thus completing the full quota of regional branches. This action has been suggested and I have been encouraged to believe that the matter is being favorably considered by many of the leaders of the group.

I am also much interested in the possible formation of a Union of American Entomologists to unite and consolidate all entomologists into a strong unit that will enable us to exert a supreme united effort in any great national emergency that may arise such as the present world war. Had such a union existed it might have been possible to place even more entomologists where they are now most needed in the control of insects affecting human health, animals, and agricultural crops.

Our relations with the American Association for the Advancement of Science, I feel, could be greatly improved for the benefit of all parties concerned if we could somehow have more adequate representation and perhaps a little to contribute in connection with the administration of Section F—Zoological Sciences. The recent lengthy discussion in Science regarding the starring of scientists in American Men of Science has some significance to our group in view of the fact that in the latest extensive lists of starred zoologists the names of only four entomologists appeared, but this matter of starring great men is not done by action of either the Association or of Section F, but rather by the publishers of American Men of Science. The number of officers elected to direct the policies and activities of Section F have been almost wholly from the zoologists and is out of all proportions with respect to membership. In 1938 Dr. Frison[1] wrote an editorial in the JOURNAL entitled: "Entomologists Don't Rate" in which he also expressed dissatisfaction with our present position in the A.A.A.S. At that time the entomologists outnumbered the zoologists about 1400 to 800. The proportions are even greater today. Invariably when this matter is brought to the attention of the officers of the A.A.A.S. the blame is placed squarely upon the shoulders of the entomologists for not taking a greater part in the affairs of Section F. Just how the participation of the entomologists would change the present condition is not stated. I am of the opinion that the only solution to the problem is to organize a separate section for the entomologists, since the objects of zoology and entomology are so widely different that there is little in common. Under present conditions there seems to be no possible way of altering this situation. It may be argued that it is due to lack of interest on the part of the entomologists, but once a group gains permanent control it is practically impossible to change the course of events no matter how earnestly a younger, though even larger, group may strive to participate. Are we to continue as a non-participating party in the A.A.A.S., or shall we make a renewed and more exerted effort to gain the representation that is rightfully our own?

Perhaps it might be worth while for the Executive Committee or some specially appointed committee to look into this matter.

Fortunately, Dr. Roger C. Smith, our delegate to the Cleveland meeting of the

[1] JOUR. ECON. ENT. 31: 635–36, 1938.

A.A.A.S. last September took this whole matter up with representatives of the national association in a manner which may result in a most satisfactory settlement of the difficulties with Section F. We may all look forward with anticipation to his report later on.

NEW INSECTICIDE TESTING LABORATORIES.—The establishment of many new insecticide testing laboratories is likely to have far-reaching effects on the toxicological work at federal and state institutions. These private laboratories are monuments to the skill, experience, and wealth of private capital—scientifically constructed and thoroughly equipped with the very latest types of machinery, instruments, and conveniences. In fact they are so much better than most of the laboratories and other facilities at our disposal at the present time as to be beyond comparison. They are also staffed with the very best men who have ability, training, and experience—many of them naturally taken from federal, state, and other public institutions whose salary scales are too low to meet the competition of private business. Under the favorable conditions provided, these investigations will no doubt continue the revolution in the development of new insecticides so well begun by the impetus of war. Even if we cannot all keep pace with these new laboratories in actual practice let us welcome them as co-workers and benefactors and fully cooperate with them in the solution of whatever problems they undertake. No doubt they will also be only too anxious to assist us in many of the tough chemical problems that are always arising in connection with the control and eradication of the many difficult entomological problems such as the Japanese beetle, the Oriental fruit moth, the pink bollworm, the sugar caneborer, the red scale, citrus and onion thrips, and others too numerous to mention. We may look upon the entrance of privately endowed research into the field of entomology as a new day in the chemical control of insects and we should adjust our programs to tie in with a united front.

ALL OUT INSECT CONTROL PROGRAM.—Never before in the history of our profession has there been such an insect-control conscious world. Entomology has come in for a big share of the interests of the medical and sanitary departments of the armed forces—among enemies and allies alike. New ideas and discoveries have created renewed interest in the control of insects and an awakened world awaits the fulfillment of a new day in relation to all fields of entomology.

In view of the great opportunities that appear to await us we as individuals and as organizations should adopt an all out insect control program! To do this it will be necessary to formulate certain definite plans which to my mind should be all inclusive.

The first requirement is an insect survey for every state or other geographical unit to determine all the species, injurious, beneficial and neutral. This is an undertaking that only a few states like Connecticut, New York, Illinois, New Jersey, North Carolina, and some others have undertaken. Every state should have such a survey under way.

The insects taken on the survey should be incorporated into a permanent technical and reference collection. In my experience this has been a difficult problem not yet solved. However, I shall consistently and constantly emphasize the importance of a complete collection until the requests have been granted and we shall have a permanent curator of insects, adequate housing facilities, equipment, and a collection.

Studies of the complete ecology of all insects in any given area will never end. Therefore, we should undertake this stupendous program with the idea that every item in the distribution, life history, habits, peculiarities, hosts, methods of dispersion, and all similar facts should be recorded and rendered available at all times.

The specific methods employed for the control of insects is a phase of entomology that is continuously changing and is becoming increasingly more difficult to keep strictly up to date on all of the very latest methods. But with additional facilities for prompt publication and the possibilities for prepublication reviews, together with abstracts, reports at meetings, and correspondence we can greatly improve sources of information.

A very important and necessary field in economic entomology that appears to be somewhat neglected is the control of insect pests by agricultural practices. While most of us recognize the value of

plowing, cultivation, methods of harvesting and storage of crops, timing of planting and gathering, effectiveness of pulverizers, weed control, burning, pruning, and a great many other common practices, yet I know of no group of entomologists anywhere who are really seriously investigating the development of this very important field. Any measures that further the use of good farming methods and at the same time afford a practical control of insect pests attains the ideal in agricultural entomology. Farming methods are constantly changing and we have ample opportunities to influence many of these changes for greater good to the farmer by controlling some of his insect pests by the same operations.

A knowledge of the natural control of insect pests is a difficult but important part of the work of the economic entomologist. We are all aware of the great good that is being done in biological control. This field of investigation is still capable of great expansion and we can hardly visualize the heights that may be attained by the expert use of bacteria, fungi, and insects in this connection.

There are also the possibilities of a greater use of unaided natural control of insects infesting agricultural crops which can only be opened to those who are capable of sizing up a situation where natural control might possibly render artificial control unnecessary. In connection with the artificial control of the alfalfa butterfly by means of dusting sulfur it has frequently been found, on careful examination, that the parasitization of the caterpillars is so high that treatment is unnecessary and useless and yet only an expert with experience is able to dispense such information to the farmer.

The possibilities of reliable insect forecasts are being appreciated more and more and it is only by careful training and long experience that this important realm can yield benefits to crop protection. It is a field that should not be neglected.

Artificial and mechanical control, although perfected to a comparatively high degree, continually lags behind new ideas and more practical and efficient methods in handling our insect problems. The shortage of manpower has given rise to the invention and manufacture of labor saving devices that permit of treating great acreages with very little labor. Such special machines are usually capable of great discharges of dusts, vapors, or sprays, and are adjusted to give complete coverages of all parts of the plants without the usual hit and miss methods formally practiced by half-hearted, spray-drenched laborers operating nozzles and spray guns at the ends of long hoses dragged about in orchards and fields. The swing towards the use of finer dusts, vapors, and sprays in quantity has been made possible only by the accessibility of equipment equal to the jobs at hand. Even greater developments along these lines are certainly ahead of us!

PLANT QUARANTINE.—The maintenance of horticultural legislation especially with regard to the introduction of pests of agricultural crops should find even a more important place than ever. The tremendous amount of shipping by water and by air from almost every conceivable place throughout the entire world is sure to bring in new pests that may prove to be very destructive and add to our already large quota of crop destroyers. E. R. Sasscer in the June issue of the JOURNAL[1] has called attention to the more salient points with regard to modern plant quarantines including the complicated problems of airmail, service mail from the armed forces, ship ballast, and seed cotton as packing material. There is also the lack of knowledge and cooperation of most small nations and persons connected with all these varied commercial activities to be contended with. Among other things he called attention to the fact that in 1943, 40 per cent of the airplanes arriving in this country carried restricted or prohibited plant materials.

Health quarantine officials are equally aware of the dangers of introducing disease-bearing and transmitting insects and are taking steps accordingly.

We are all affected by and interested in these legal phases of entomology and should give them our close attention and continued hearty support.

INSECT EXTERMINATION.—One of the most promising prospects in the future control of noxious insects is the strong emphasis being placed on the complete extermination of not only newly introduced pests but also those of long standing in the country. We are already familiar

[1] JOUR. ECON. ENT. 37: 356–59, 1944.

with the successes attained in eradicating the Mediterranean fruitfly in Florida, and the present campaigns being conducted against the Mexican fruitfly, the pink bollworm, and the sweetpotato weevil in the South and the pear psylla in the Pacific Northwest. There are no longer doubts in the minds of well-informed entomologists as to the possibility and practicality of major insect extermination campaigns. They require good leadership, generous support, great manpower, and perseverance. Following the close of the war, when employment is likely to be needed, such campaigns may serve a dual purpose in ridding the country of serious pests and in giving necessary work to qualified deserving men and women.

It is not too extravagant to believe that such important destructive insects as the gypsy moth, brown-tail moth, Japanese beetle, all species of *Anopheles*, bedbugs, human louse, common species of fleas, and many others can be completely eradicated in this country. Should we not support such a worthy plan of future procedure?

AID TO FOREIGN COUNTRIES.—In our postwar program we may have exceptional opportunities to do great service in the re-establishment and future development of entomology in many of the countries now being devastated by war. It is needless to say that it will take some of these countries years to restore their once well organized entomological work, their museums, their insect collections, and their libraries, to normalcy. Many of these countries like China, Poland, Czechoslovakia, and possibly others, are very likely to be in dire need of immediate help. Their universities, libraries, museums, and laboratories have been destroyed, their scientists killed, and their countries devastated almost beyond repair. Much that will be needed cannot be readily obtained by money.

While it is to be supposed that all of us who have had a kind of professional comradeship with entomologists in certain of these countries will want to do everything possible to assist them in every manner in supplying literature, insect specimens, and supplies, there are larger tasks such as national planning and cooperation that are beyond the responsibilities of individuals and should be taken over by our governmental agencies, philanthropic enterprises, and possibly also by entomological organizations like our own. I cannot think of anything more worth while than for us to consider doing some of these things as a part of our postwar program.—12-13-44.

Medical Entomology Meets the Impact of War[1]

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One of the earliest comprehensive courses (lectures and laboratory exercises) entitled Medical Entomology was given by the writer at the University of California for the first time in 1909 and each year since except for the periods while he was on active military duty. The scope and methods of this course were described in the JOURNAL OF ECONOMIC ENTOMOLOGY for August 1909 (Herms) and briefly characterized by the following excerpts: "need for men . . . who are not only equipped entomologically, but who also have knowledge of certain diseases and of pathogenic organisms . . . and the laboratory methods involved." . . . "It is essential that the student become familiar with the habits and habitats of (the offending) insects in the field." . . . "The aim of our work should never be lost sight of—the *control* of disease-transmitting insects." I believe we have adhered closely to these guiding principles through the years. Many institutions throughout America have offered courses entitled "Medical Entomology" since 1920.

Relatively few of the students who took the course in Medical Entomology at Berkeley prior to 1918 became involved in World War I and of these few the writer, who was then on active duty and assigned to the then Southern Department Laboratory, Fort Sam Houston, Texas, used several as enlisted men and non-coms. The number of commissioned officers on

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duty in the Sanitary Corps of the Army in the technical capacity of entomologists and parasitologists during World War I was very small, probably not over six or eight. At Fort Sam Houston my duties concerned mosquito problems, particularly anopheline, hookworm survey, and a variety of situations in military field sanitation. Upon transfer to the Port of Embarkation (Newport News, Va.) the "malaria drainage detachment," comprising about 300 officers and men, was placed in my charge as well as large-scale delousing operations and again a great variety of duties as "Assistant Port Sanitary Inspector" (see "Parasitology as an aid to the Medical Officer," the Military Surgeon, Nov. 1925). Dr. Freeborn gave much valuable assistance during this period and took over that work when I returned to Berkeley early in 1919.

This background of military experience, particularly in the Medical Department of the Army, together with some early experience as an infantryman, no doubt, caused me to give emphasis to medico-military problems in my course in "Medical Entomology" particularly from 1919 on. Many of my former students now on duty as sanitary officers in World War II have reminded me of this and have expressed approval. A number of these young officers came in contact with me again during my tour of duty at the Medical Field Service School (Carlisle Barracks, Pa.) in 1943, where my lectures (there was very little field duty in contrast to 1918) covered a wide variety of topics in military sanitation, particularly military malaria control, helminthic infections such as filariasis, ancylostomiasis, and schistosomiasis, venomous snakes, and a consideration of a wide variety of infections caused or carried by insects and arachnids. Again my duties were very broad, a matter I wish to emphasize because it gives point to my constant insistence upon breadth of training for those concerned with medical entomology (see particularly my paper entitled, "Preparation for a career as a Medical Entomologist" in the JOURNAL OF ECONOMIC ENTOMOLOGY, February 1943).

The young officer who is commissioned in the Medical Departments of the Army or Navy, presumably as an entomologist soon discovers that he is primarily a "sanitary officer" and may become a "medical inspector" at an important camp or station with little or no time for strictly orthodox entomological pursuits such as collecting insects, mounting them and naming them. I have heard several young entomologists bemoan the fact that they couldn't find time to make a collection of insects in an area in which they had never been before.

As "medical inspector" or as assistant, the officer is under command of the Camp or Station Surgeon and usually has an office at the hospital. Under such conditions he is far more comfortable if he has some familiarity with medical terminology and medico-sanitary procedures. The entomologist discovers that "he is in the Army now" and as such he must win his way. The Medical Corps officers consider it quite unlikely that an entomologist who presumably only knows "bugs" can also make blood smears and identify plasmodia of malaria; certainly his knowledge of such infections as ancylostomiasis, schistosomiasis, filariasis, scrub typhus, and others, would normally be nil. It is therefore a revelation when a young Sanitary Corps officer with a well-rounded training in medical entomology and parasitology reports for duty.

During my tour of duty in 1943, I was in close contact with numerous Sanitary Corps officers labelled entomologists who had received their training in entomology in various American colleges and universities. Hence I was able to make comparisons, and later, upon my return to "Inactive status" many young officers have stopped over to visit me in Berkeley on their way to various assignments in the Pacific theatres of war. These officers very freely told me of their misgivings on being precipitated into a situation of grim wartime reality. They (and they continue to come) are eager to receive as much "down to earth" instruction as can be had in those fleeting moments before leaving. After they arrive on one of the Pacific Islands their reactions are best described by quoting from a few V-mail letters. Here is one, "I have never been able to appreciate to quite as full an extent, the subject matter which you primed us with in your medical entomology courses, as during this experience. Tropical diseases—malaria, dengue, filariasis, hookworm, dysentery, fungus infections, scrub typhus, yaws, etc., all passed in

review. . . . At present I am preparing to teach line and medical officers the entomology of the tropics and how to *avoid* getting malaria." Here is another one from New Guinea: "I miss seeing the current literature while here. That is one of the main drawbacks. What I would give to sit in on one of the old seminars and participate in discussions again." This one is a bit different: "We spent nine days here sanitating (?) the island of —— and our chief concern was the disposal of the numerous enemy dead—a not too pleasant job." The disposal of dead bodies has entomological implications, namely flies. This quotation from another of our boys is very interesting: "Expect to see more of scrub typhus, filariasis, schistosomiasis and even more plague than I had thought likely. While malaria is always a threat, it is pretty well under control. *Anopheles punctulatus moluccensis* and *typicus* are the only important vectors here. We do have some *Bironella* however." Quotations from numerous other letters would further illustrate how our medical entomologists are meeting the situation, but finally these words from another of our boys: "I am going to be doing some intensive mite collecting searching for the vector of tsutsugamushi. . . . Would you please find an adequate key. . . . I made quite a number of blood smears of natives in —— and —— and have several good slides of filariasis." Letters from the field also tell of the many improvements and aids which have become available in World War II such as the *Freon* aerosol bombs, repellents, visual aids, and not the least of these the insecticide DDT.

World War II as of June 1, 1944 finds 45 alumni of the Division of Entomology and Parasitology, University of California, holding commissions in the Medical Departments of the Army and Navy and the United States Public Health Service (23 Army, 15 Navy and 7 Public Health Service). Of these, 23 hold doctorates, 19 from the University of California, and all but three of the 45 took our course in medical entomology, hence were trained for many of the specific duties which they must perform as sanitary officers. Nearly all had special supplemental training at medical centers of the Army and Navy such as Camp Barkeley, Carlisle Barracks and Bethesda.

To say that those officers who were trained in general entomology alone are doing as well in a military capacity as those who had specific training in medical entomology is not a fair judgment so far as it pertains to the 45 men referred to above. They are *all* fundamentally well trained in entomology; only three had no formal course in medical entomology.

My only concern is that the training *all* these young officers received at the University of California is helpful to them now. There should be no argument as to the necessity for the best training available in entomology—this has been my preachment through the years. To make odious comparisons in these serious times is highly inappropriate. We should be thankful that our science (entomology) is in a position to make a substantial contribution toward the winning of World War II. The men who are meeting the real impact of war in the various theatres of operation are the ones who will have the final answers—not the classroom professor unfamiliar with military necessity. World War II has definitely proved that medical entomology is not a narrow specialty easily picked up, as some uninformed entomologists would have us believe. It is quite true that two or three weeks of laboratory and field training may be sufficient to prepare a capable entomologist for his share in mosquito control operations, but the concern of this paper is *medical entomology* with its experimental, ecological and parasitological implications and the necessarily wide knowledge of arthropods.

It is unlikely that many entomologists will choose medical entomology as a career for several reasons, (1) a fundamental interest in public health is essential to success; (2) working with parasitic infections of man and animals is often very unpleasant business, e.g. myiasis, hookworm survey and the like; (3) exacting requirements in bacteriology, protozoology, pathology and other subject matter not strictly entomological; (4) high degree of responsibility in dealing with infectious diseases. War-time experiences will have a decided selective effect, —many will return to the more agreeable plant-protection aspects of entomology, or its more strictly systematic, morphological or physiological phases. Medical entomology, strictly speaking, is not just a happy, fascinating search for new

species on tropical islands, granting the full importance of that aspect of entomology. As indicated by the excerpts from letters cited above, the medical entomologist must be highly trained in systematics and taxonomy; his responsibility in this respect is heavy. The impact of war emphasizes the necessity for the best possible training in the taxonomy of arthropods, since species sanitation rests upon this knowledge.

The content of medical entomology can be greatly enriched and made more authoritative if teachers will exert themselves to gain field experience. Medical entomologists stationed in the various tropical war areas will bring back a wealth of experience which will mean much to future students—another valuable outcome of war. The fortunes, or shall I say misfortunes, of war gave some color to *my* teaching, but enrichment came out of such experiences as a term spent in England and on the continent visiting most of the important European centers of tropical medicine, and secondly by my experiences in the tropics. Nothing could have given me a better knowledge of the medical entomological problems of California than the statewide malaria-mosquito survey which took our group into practically every nook and corner of the state. Nothing can take the place of field experience and in addition we enjoyed the advantage of organizing and operating a number of mosquito control districts as early as 1911. I can heartily recommend the ecological approach in all of our entomological work that pertains to insect control.

As my academic career draws to a close, I may look upon the past 35 years with at least some degree of satisfaction. Medical entomology has grown up in this time and is making a "man-sized" contribution during these years of another World War, and we may expect the white heat of war to refine this phase of entomology as it surely will all others. Entomology has contributed much to the welfare of mankind. I have seen much of its fruition during my lifetime. Entomologists must not now start clawing at each other, believing one phase to be purer and more lofty than another, and sneer at the entomologist who would see a better world by combating the louse, the flea, the mosquito, and applauding the other who would save crops by combating the grasshopper, the chinch bug or the plant louse.

SUMMARY.—Our entomologists now commissioned in the medical departments of the Army and the Navy and the Public Health Service are doing an excellent wartime job and are gaining approval in military circles. The title medical entomologist is being more widely used and more generally recognized as a distinctive profession.

Medical entomology is by no means a narrow specialty. Wartime experience has demonstrated the value of breadth of training as set forth in an adequate curriculum of medical entomology. Greater stress must be placed upon field experience as an integral part of such training.

The impact of war shows the need of greater stress upon taxonomic and systematic knowledge particularly of arthropodan groups of public health and medical importance such as the Culicidae, Phlebotomini, Siphonaptera and Acarina (ticks and mites).

Much more stress needs to be placed upon ecology and host-parasite relationships as a basis for intelligent and economical control of vector species—species sanitation.

Greater stress should be placed upon the geography of disease as pertains to arthropod-borne infections. The fundamental ecological reasons for geographical distribution must receive greater attention.

Teachers of medical entomology greatly need tropical field experience. There should be many experienced young men ready for positions in the field of medical entomology and parasitology at the close of World War II.—8-28-44.

Biological Races of the Pea Aphid

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Since entering the United States about 75 years ago, the pea aphid, *Macrosiphum pisi* Kalt., has become established in practically every section of the nation where its leguminous host plants are found. Long considered a major pest of garden, field and sweet peas, of alfalfa, vetch, red clover and other forage crops, the insect has been subject to intensive investigation by various federal, state, and private agencies for the past 40 years.

The first comprehensive studies of its biology in the United States were published by J. J. Davis in 1915, and by L. B. Smith in 1916. The Davis investigations were carried on in Indiana, the Smith studies in Virginia. Both these workers were interested in determining the life history of the insect under natural conditions, the work being done in insectaries and field cages. In 1926 Campbell released results of his studies of the aphid biology under California conditions. In these three papers the role of temperature in determining rates of aphid development and reproduction was pointed out. Following this lead, C. W. Schaefer[2] made a detailed study of the relation of temperature to development and reproduction of the aphid. Schaefer's results were not published in a technical journal because they were considered as too closely parallel to those of Campbell. Actually his investigations were carried one step further due to his use of the degree-hour concept in the temperature studies.

In 1931 E. M. Searls (1932) presented the first recorded evidence that resistance to the pea aphid is present in some varieties of its host plants. A large number of pea varieties were tested for aphid resistance by Searls and Maltais (Maltais 1937) and results of both workers showed that pea varieties differed markedly in resistance. Subsequent studies by Searls (1938), based on tests of massed hybrid plants, established the inherited nature of aphid resistance in peas. The testing procedures used by Searls and Maltais were based on field trials involving periodic counts of aphid populations on massed plants of the varieties under test. Because these procedures could not be satisfactorily adapted to detect the presence of resistance in individual plants belonging to small segregating populations, pea breeders were unable to include aphid resistance in their pea improvement programs. In 1940 several detailed studies involving the influence of aphid resistance on the aphid biology (Harrington & Searls 1940) (Harrington 1941) were undertaken in an effort to discover a more efficient testing procedure. Results secured through study of the effect of plant resistance on aphid reproductive rates pointed the way toward development of a new testing procedure (Harrington 1943). The accuracy of this procedure in determining the presence and extent of aphid resistance in individual plants is due to the fact that aphid reproduction on the plants is measured in terms of accumulated effective degree-hours of temperature. This application of the degree-hour concept to the procedure was based on results of Schaefer's studies.

The possibility that there might be more than one biological race of the pea aphid was recognized by the writer in 1939 (Harrington 1941). The question did not assume major importance, however, until the new aphid resistance testing procedure was developed. It then became apparent that if more than one race of the insect did exist, the separate races should be described and their comparative virulence measured in order that the most virulent race might be available to the pea breeder for his testing work. Work was accordingly begun in the fall of 1941 to determine if more than one biological race of the pea aphid is present in the United States. The purpose of this paper is to present the procedures, data, and conclusions drawn from these investigations.

Source of Aphid Lines.—The means by which the pea aphid have been able to accomplish such complete and widespread

[1] Entomologist and plant breeder, Associated Seed Growers, Inc., New Haven, Conn. The writer wishes to acknowledge the helpful advice and cooperation of Drs. G. W. Scott and W. H. Pierce, staff geneticists. The illustrations used in the paper were from photographs taken by Dr. Scott. The writer is also indebted to Dr. J. Neyman of the University of California Statistical Laboratory at Berkeley for his aid in the statistical analysis of the 1942 virulence data; to Dr. E. O. Essig, Division of Entomology, University of California for taxonomic identification of the aphid lines involved; and to the collaborators in many states who contributed the aphid stocks.

[2] Schaefer, C. W. The relation of temperature to the development and reproduction of the pea aphid *Illinoia pisi* Kalt. M. S. Thesis, Dept. Econ. Ent., Univ. Wis.

dispersal over the United States in less than 50 years has long been a point of controversy. Many competent entomologists maintain the migrant forms of the insect are carried great distances by high winds. Circumstantial evidence supporting this hypothesis is that old and battered alate aphids have been found in far northern states in early spring before alate young arising from indigenous stem mothers have reached maturity. Many workers believe these aphids were carried northward from the Gulf States by high air currents.

There are many areas in the United States, however, where natural barriers such as high mountain ranges, large bodies of water, and wide desert areas devoid of leguminous host plants prevent, to a large extent, the possibility of successful wind blown dispersal. If aphids now present in isolated areas of this type were originally brought in by man and not renewed annually by wind currents, then the possibility exists that continued isolation of these insects may have resulted in the development of separate biological races. Mutation, natural selection, or eventual change of a heterogeneous original stock to a pure line through years of close inbreeding might well produce this result.

Because of this possibility an attempt was made to collect aphid stocks from a number of widely separated geographic regions. Choice of the localities was determined by geographical barriers surrounding them and by their importance from the pea growing standpoint. Four geographical areas were recognized (1) the plateau and coastal plains east of the Appalachians, (2) the Mississippi watershed, (3) high mountain valleys west of the continental divide, and (4) the Pacific Slope. Stocks were received and reared successfully from 9 of 10 sources in 1941 and from 12 of 15 sources in 1942. The source and identity of the 31 lines dealt with in this paper are as follows:

GEOGRAPHICAL REGION	SOURCE	COLLABORATOR	IDENTITY OF LINE[1]
1	New Brunswick, N. J.	B. B. Pepper	NJ41, NJ42-1, NJ42-2
	Blacksburg, Va.	S. A. Wingard	V41, V42
	Auburn, Ala.	H. S. Nation	A41, A42-1, A42-2
2	Manhattan, Kan.	R. H. Painter	K41, K42
	Madison, Wis.	E. M. Searls	W41-1, W41-2, W42-1, W42-2 W42-3, W42-4, W42-5, W42-6
	Fargo, N. D.	J. A. Monro and H. S. Telford	ND42
	Lexington, Ky.	H. H. Jewett	Ky42-1, Ky42-2, Ky42-3
3	Hamilton, Mont.	W. H. Pierce	M42
	Logan, Utah	G. F. Knowlton	U41, U42
4	Alhambra, Calif.	R. E. Campbell	CA42
	Milpitas, Calif.	C. D. Harrington	CM41, CM42-1, CM42-2
	Corvallis, Ore.	K. W. Gray	O41, O42

[1] Throughout this paper the word "line" indicates a parthenogenetic pure line. Aphid lines are identified as to source by the first letter of the state source except in those cases where two states begin with the same letter. Here a qualifying letter is added to separate the lines. The numbers 41 and 42 indicate year of collection. In cases where more than one line was isolated from the same source, the lines are numbered consecutively —1, —2, etc. Where two stocks were received from the same state, the first letter of the city of origin is added to the state source symbol.

Aphid stocks received from Montana in 1941 and from Idaho, Indiana and New York in 1942 were preponderantly oviparous on arrival. Viviparous forms were isolated but without success, since the proportion of sexual to viviparous young increased with each generation until all were oviparous. Both elate and alate males were observed in these stocks. Requests for aphids from Texas, Florida, Colorado, and Washington were unsuccessful because of aphid scarcity in the areas at the time. Representative aphids from each of the 1941 lines were sent to Dr. E. O. Essig, of the Division of Entomology, University of California, at Berkeley, for taxonomic verification of the species involved. In 1942 a series of slides was prepared containing both elate and alate adult viviparous aphids from each of the 12 state sources. These also were examined by Dr. Essig, and, like the 1941 stocks, all were classed as *Macrosiphum pisi*.

PROCEDURES FOR REARING.—Immedi-

ately on receipt of the aphid collections the insects were transferred to seedling plants of the Perfection pea variety growing in 6-inch pots. When they recovered from the effects of shipment, 1 to 10 parthenogenetic pure lines were started from each stock through isolation of individual viviparous adults and their subsequent progenies. Many lines were lost due to oviparity and many were discarded because the number became too great to handle. The 31 lines eventually selected for testing were carried through 7 to 12 generations before actual testing was begun in order that all might be completely adapted to conditions of the greenhouse. The aphid lines were kept on a separate greenhouse bench. Stock pots of each pure line were isolated from other lines by placing them in separate water-filled trays. In addition to this water moat, all stock pots were covered by 16-mesh wire cages.

The insects were reared by successive generations. As soon as the first born young of one generation reached reproductive maturity, five individuals were transferred to new stock pots. After 6 to 8 hours of reproduction, the five parent insects were removed, leaving the young aphids of the next generation in place. This procedure insures uniformity of the aphid stock, permits close control of aphid numbers, and prevents, to a large extent, any increase in aphid parasites, predators, or diseases which may have been present in the original collection. The frequent transfers from old to new stock pots were made on a small metal table, surrounded by a water moat. Only one aphid line was handled at a time, after which the table and all other equipment employed were thoroughly cleaned to kill possible stray aphids. All excess aphids and plants of discarded stock pots were promptly destroyed.

COMPARATIVE INJURY OF 1941 LINES.—The nine 1941 aphid lines were collected in the fall of 1941 and tested in the spring of 1942. During the winter it was noted that certain of the aphid lines appeared to cause greater injury to their Perfection host plants than did other lines. This indicated that differences in virulence might be present among them. To check this point a series of 100 pots was planted singly with Perfection peas, and a similar series to peas of the Onward variety. On March 12, 24 plants of nearly identical size and vigor were selected from each 100-plant array. The selected plants of each variety were then arranged into 12 pairs. Three pairs, or six plants, were set aside as checks, and the nine remaining pairs were infested with fourth-instar aphids of the nine aphid lines. These aphids were born during the same 4-hour period and reared on young and succulent Perfection plants. The rate of infestation was 20 aphids per plant. The insects began to reproduce on March 15, and by March 18 differences in the amount of feeding injury caused by aphids of the separate lines became noticeable. A series of photographs was taken on March 19. The least injured plant of each pair was selected for this purpose. No detailed counts of aphid numbers or measurements of plant injury were undertaken because other experiments involving aphid size and reproductive rates were planned. The results of the experiment are expressed photographically in figure 1.

It will be noticed that plants of the aphid-susceptible Perfection variety as a group were more seriously injured than those of the Onward variety which has been considered as having some resistance to the pea aphid (Searls 1935) (Harrington *et al.* 1943). In the case of the O and A aphid lines, however, the Onward plants appeared to have suffered as much as those of the Perfection variety. This appears to be true also, in the case of the W.L. and the V aphids, but to a smaller extent. Results of this elementary experiment indicate that the nine aphid lines do differ in their ability to injure their host plants, lines O, A, W.L. and V being most active in this respect.

COMPARATIVE BODY SIZE.—Size differences in insects are of questionable value because of many environmental factors influencing the insect biology. This is especially true with aphids because of their extreme sensitivity to changes in temperature and food conditions (Ewing 1916). As an example, aphids of line CM41 grown under sunny spring conditions on succulent Perfection plants averaged 3.35 mm. in length (tip of head to base of ovipositor) and 1.49 mm. in width at widest portion of the abdomen. Aphids of the same line when reared under cool and cloudy mid-winter conditions on partially etiolated plants of the same variety

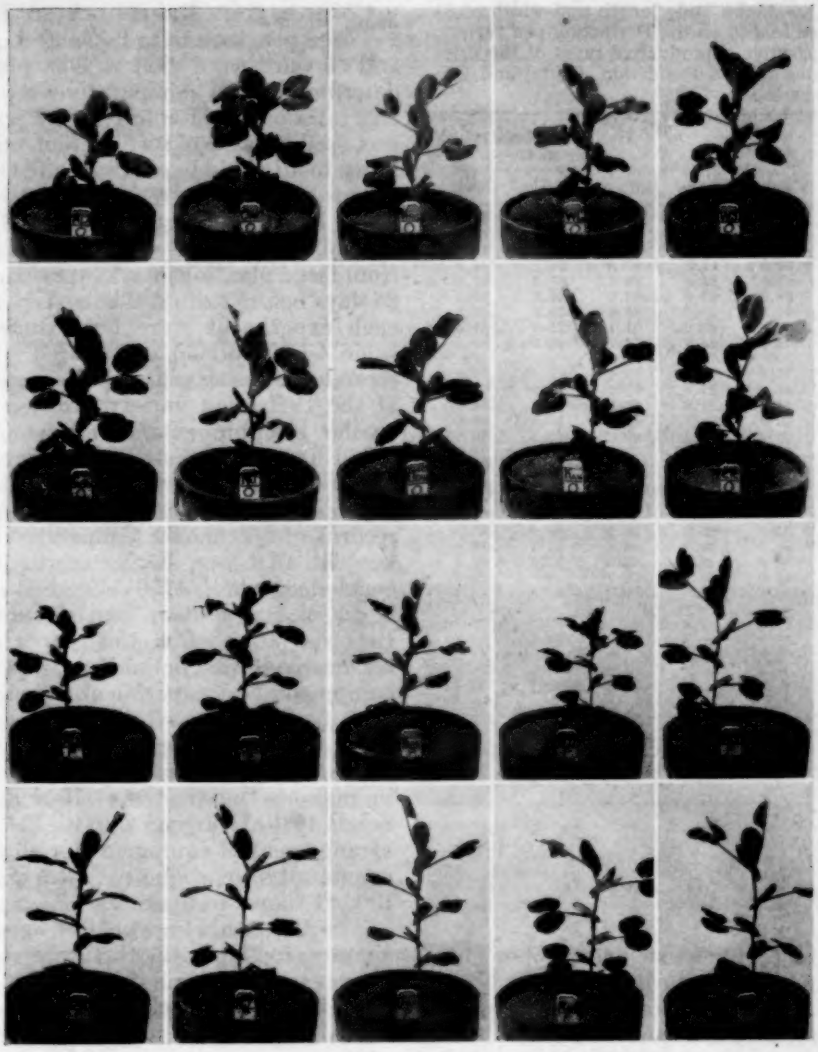

FIG. 1.—Differential feeding injury caused by 9 aphid lines on plants of the Onward (O) and Perfection (P) pea varieties. Note increased stunting and malformation of the terminal growth on plants infested with aphids from A(labama), O(regon), V(irginia), and W(isconsin) (WL) as compared to plants infested with other and less virulent aphid lines. W.L. and W.S., both from Wisconsin, are referred to as W41-1 and W41-2, respectively, in the text. The difference in the virulence of these 2 lines is noteworthy, since this is the first indication that more than one biological race may be present in the same area. The check plants for each variety are labeled Ch.

were 3.04 mm. long and 1.41 mm. wide. When reared on plants of the Onward variety under winter conditions the insects were 2.04 mm. in length and 1.08 mm. in width.

It was noticed early in 1941, however, that aphids of the various lines reared under nearly similar environmental conditions appeared to differ considerably in size. The consistent nature of these size variations, observed over several generations, led to the conclusion that they resulted from inherent differences in the aphid lines themselves, and were not due to fluctuating environmental conditions. To check this point, 50 adult aphids of each line were carefully measured by means of a calibrated lens mounted in the

Table 1.—Mean body length and width of 31 aphid lines reared on the Perfection pea variety, and comparative reproductive rates of the lines when tested on the Perfection, Pride, and Onward pea varieties.

Aphid Line	Mean Body Length[1]	Mean Body Width[1]	Average Progeny Produced On[2]		
			Perfection	Pride	Onward
A41	61.4	24.3	97.4	81.8	88.0
CM41	50.2	22.4	64.4	40.9	21.5
K41	53.0	23.9	67.3	40.3	22.4
NJ41	52.8	22.8	67.5	34.1	22.0
O41	63.3	24.0	93.0	87.4	81.4
U41	52.8	23.8	65.2	34.7	25.8
V41	54.5	23.7	86.2	60.7	66.3
W41-1	55.9	23.2	91.1	75.9	81.3
W41-2	52.1	24.1	77.7	40.7	32.8
A42-1	51.3	22.8	79.4	77.4[4]	76.2
A42-2	51.4	21.8	77.5[8]	74.9[6]	71.9[9]
CM42-1	47.7	21.6	53.6	38.7	29.3
CA42	49.9	21.7	51.2	48.2	42.1
K42	49.2	23.2	60.7	56.5	38.5
KY42-1	48.8	22.0	57.9	44.2	21.3
M42	58.2	23.3	88.0[8]	82.3[9]	81.6
NJ42-1	50.8	22.8	64.0[9]	40.4	17.3
ND42	52.5	22.7	80.0[9]	75.3[9]	69.5
O42	58.6	23.8	90.0[8]	83.4[7]	80.2
U42	51.2	23.5	63.0[7]	44.2	25.8
V42	49.1	22.1	48.3	25.1	16.0
W42-1	50.6	23.1	63.8	35.9	30.6
W42-2	49.9	23.2	66.7[6]	—	24.9
W42-5	51.8	22.7	60.9[9]	26.0	28.7
A42-2	51.4	21.8	83.4	80.8[9]	77.3
M42	58.2	23.3	96.2	89.7[9]	81.3
ND42	52.5	22.7	—	81.0[9]	71.5
O42	58.6	23.8	93.0[9]	84.8[9]	80.7[7]
CM42-2	49.6	23.1	58.5	50.7	26.2
KY42-2	51.2	23.1	68.8[5]	53.9	22.2
KY42-3	51.7	23.5	65.4	42.9	30.2
NJ42-2	50.3	23.2	67.9[9]	53.2	22.3
W42-3	52.2	23.4	66.3	42.3	19.6
W42-4	52.2	23.8	69.6	52.1	19.4
W42-6	52.8	23.5	65.3	50.0	18.3

[1] Measurements expressed in units of calibrated lens where 1 unit equals 0.066 mm.

[2] Averages based on progenies of 10 aphids except for some cases where disease or injury to parent aphid caused the counts to be discarded. These averages are followed by subnumerals indicating number of samples.

eyepiece of a binocular microscope. These aphids were born during the same 6-hour period and were reared to full reproductive maturity on succulent Perfection peas. Measurements for body length included the distance from the tip of the head to the base of the ovipositor; those for width, the distance across the insect, dorsal aspect, at the widest portion of the abdomen. The data are expressed in units of the calibrated lens. Each unit of the scale equals approximately 0.066 mm. The 22 aphid lines of 1942 were measured on 3 separate dates over a 7-day period. A line from each of the 12 sources was measured January 31, the remaining 10 lines were measured February 5 and 6. At the time of actual measuring, however, the aphids of all lines were of comparable age in number of days from time of birth. Results of all measurements are presented in table 1.

Comparative Reproductive Rates.—Three pea varieties, Perfection, Pride, and Onward were used as host plants in determining the comparative reproductive rates of the 31 aphid lines. Perfection was used because of its apparent susceptibility to all aphid lines; Pride and Onward because of partial resistance to certain aphid lines (Harrington *et al.* 1943). The test plants were selected for uniformity from large plantings made approximately 25 days before testing. The aphids used in each experiment were born during the same 4-hour period and reared to early reproductive maturity on young plants of the Perfection variety growing under similar environmental conditions. Each aphid line, when tested, was represented by 10 aphids confined individually to 10 plants of each pea variety. Thermographic records of greenhouse temperatures were kept at all times. Each experiment was concluded when 4750 effective degree-hours of temperature had accumulated. In order to confine this paper within reasonable limits, detailed descriptions of equipment and experimental procedures have been eliminated. This omission appears justified since the equipment and procedure used have been described in previous publications (Harrington & Searls 1940) (Harrington *et al.* 1943). The arrangement of equipment for all tests of comparative reproductive rates is similar to that shown in figure 2.

The nine aphid lines of 1941 were tested simultaneously on the three pea varieties. The experiment included 270 plants mounted in 54 testing racks. The individual testing rack containing five plants of the same pea variety, infested with five aphids of the same line, was used as the basic unit in the design of the experiment. The testing racks were arranged in random order in two rows of 27 racks each for the actual testing.

The necessity of fitting the 1942 aphid line experiments into a closely filled schedule of other work prevented simultaneous testing of the 22 aphid lines. It was found expedient, therefore, to divide the lines into two groups and to test them in two series of three experiments each. The first group, made up of 15 aphid lines, contained at least one representative line from each of the twelve 1942 sources. The group was tested successively on Perfection, Pride, and Onward. The second

Table 2.—Intersection table showing the mean body length of the 9 1941 aphid lines and the mean differences for all paired combinations between the lines.

LINE →		CM41	W41-2	NJ41	U41	K41	V41	W41-1	A41
↓	Mean	50.22	52.10	52.76	52.76	53.02	54.50	55.94	61.40
O41	63.30	13.08**	11.20**	10.54**	10.54**	10.28**	8.80**	7.36**	1.90**
A41	61.40	11.18**	9.30**	8.64**	8.64**	8.38**	6.90**	5.46**	
W41-1	55.94	5.72**	3.84**	3.18**	3.18**	2.92**	1.44**		
V41	54.50	4.28**	2.40**	1.74	1.74	1.48			
K41	53.02	2.80**	0.92*	0.26	0.26				
U41	52.76	2.54**	0.66	0.0					
NJ41	52.76	2.54**	0.66						
W41-2	52.10	1.88**							

* Difference significant, odds 19–1.
** Difference very significant, odds greater than 99–1 that difference of such magnitude is not due to chance alone.

series of experiments contained the remaining lines together with certain lines selected from the first series because of their rapid reproductive rates. These were classed as virulent check lines. In the 1942 tests the aphids were arranged in random order over the entire experiment. This was accomplished by assigning a number to each aphid. The order in which these numbers were drawn from a container, after adequate mixing, determined the particular rack and position on the rack each aphid was to occupy. The average numbers of progeny produced by the 31 aphid lines in the seven experiments of 1941 and 1942 are given in columns 4 to 6 of table 1.

STATISTICAL TREATMENT OF THE DATA.—The data secured through measuring 50 individual aphids from each of the nine 1941 lines were arranged into frequency distributions, and the standard error and mean of each was computed. The mean values secured for the nine lines were then compared in all of the 36 possible paired combinations, "Student's" t-test being utilized to determine the degree of confidence which could be attributed to the mean differences noted. The magnitude of size differences among aphid lines within the pea aphid species is illustrated by table 2 which shows the body length comparisons of the nine 1941 lines.

Table 3.—Composite analysis of variance of comparative reproductive rates of the 9 1941 aphid lines confined to 3 pea varieties.[1]

VARIATION	SUM OF SQUARES	DEGREES OF FREEDOM	MEAN SQUARE (VARIANCE)	Z VALUE
Aphid lines	105,878.0	8	13,234.75	2.536**
Pea varieties	43,636.0	2	21,818.00	2.787**
Replicates	734.0	9	81.55	0.0
Lines×varieties	12,430.6	16	776.91	1.119**
Lines×replicates	9,214.6	72	127.98	0.216**
Varieties×replicates	2,058.0	18	114.33	0.161
Lines×varieties ×replicates	11,942.8	144	82.94	
Total	185,894.0	269		

** Value significant at .01 level (odds 99–1 that variation is not due to chance alone).
[1] In testing the variances (mean square deviations) the interaction of lines×varieties×replicates is used as the comparison term. The mean square deviation for replicates is not significant, since it is smaller than the comparison term.

FIG. 2.—Arrangement of equipment used to determine the comparative reproductive rates of the 31 aphid lines tested in 1941–42. Note thermograph, power aspirator for removing aphids from plants at close of experiment, and younger plants in background and on side bench for subsequent tests.

The 1942 data on aphid size were treated similarly, except that no attempt was made to compare aphid lines measured on different dates. Intersection tables like table 2 were prepared for the body length and body width measurements of each group of lines. Results closely paralleled those of table 2 for the preceding year with respect to the magnitude of the size differences between the lines. Within individual lines, variation was extremely small.

Table 4.—Intersection table showing comparative reproductive rates of 9 1941 aphid lines on the Perfection pea variety.

LINE →		C41	U41	K41	NJ41	W41-2	V41	W41-1	O41
↓	Mean	64.4	65.2	67.3	67.5	77.7	86.2	91.1	93.0
A41	97.4	33.0**	32.2**	30.1**	29.9**	19.7**	11.2**	6.3*	4.4
O41	93.0	28.6**	27.8**	25.7**	25.5**	15.3**	6.8**	1.9	
W41-1	91.1	26.7**	25.9**	23.8**	23.6**	13.4**	4.9**		
V41	86.2	21.8**	21.0**	18.9**	18.7**	8.5**			
W41-2	77.7	13.3**	12.5**	10.4**	10.2**				
NJ41	67.5	3.1	2.3	0.2					
K41	67.3	2.9	2.1						
U41	65.2	0.8							

* Significant difference, odds 19–1.
** Difference highly significant, odds 99–1 such difference not due to chance.

COMPARATIVE REPRODUCTIVE RATES.—The data obtained from testing the comparative reproductive rates of the 1941 aphid lines were subjected to the analysis of variance procedure. Results are presented in table 3.

Table 3 indicates that the chief source of variation is due to aphid lines and pea varieties with only a negligible portion being due to replication. This point being settled, the examination of differences between lines within each of the three pea varieties was undertaken. For this purpose "Student's" t-test was employed. A sample of results is presented in table 4.

The reaction of the aphid lines between varieties were also compared by the t-test procedure to determine if differences in reproductive rates of the nine aphid lines behaved consistently with respect to added resistance of the host plants, *i.e.*, produced uniformly fewer young on Pride than on Perfection, and fewer on Onward than on Pride. The results are summarized in table 5.

As previously stated 22 aphid lines representing 12 state sources were selected for testing in 1942. The first 3 experiments, 1, 2, and 3, were run on Perfection, Pride, and Onward, respectively, and contained 15 aphid lines. Five of the 15 lines were from two state sources, and since the sister lines from each of these states appeared to be similar, three were dropped from the analysis. The analysis of experiments 1 to 3 is concerned, therefore, with twelve aphid lines from the twelve separate state sources. Three additional experiments, 4, 5, and 6, contained the remaining seven lines not tested in the earlier experiments. The data from these experiments were given the same statistical treatment as that of experiments 1 to 3.

Because of the necessity of discarding progeny counts of several parent aphids which contracted bacterial disease in experiments 1 to 3, the usual analysis of variance procedure could not be used. The problem was referred to Dr. J. Neyman of the University of California Statistical Laboratory at Berkeley. Dr. Neyman suggested a method involving weighted values whereby the variation of each experiment might be measured separately by means of the F-test. Using this formula, F was calculated for experiments 1 to 3 as 397.0, 339.24, and 925.12, respectively. These values are highly significant, since the F value for odds of 99 to 1 is 3.70. Consequently it must be assumed that within each experiment the large variation found was due principally to differences among the aphid lines.

The mean values secured for the twelve aphid lines were compared with one another in all possible paired combinations, "Student's" t-test being used, as

Table 5.—Comparative reaction of the 9 1941 aphid lines to 3 pea varieties differing in amounts of resistance to aphid attack.

Varieties Compared	D41	A41	V41	W41-1	W41-2	C41	U41	NJ41	K41
Perfection with Pride	5.6	15.6**	25.5**	20.8**	28.0**	23.5**	30.5**	33.4**	27.0**
Perfection with Onward	11.6*	9.4**	19.9**	9.8**	44.9**	42.9**	39.4**	45.4**	44.9**
Pride with Onward	6.0	6.2	5.6	5.4	16.9**	19.4**	8.9*	12.1**	17.9**

* Significant difference, odds 19–1.
** Difference highly significant, odds 99–1 such difference not due to chance.

with the 1941 data, to determine the degree of confidence which might be safely applied to the mean differences noted.

SIZE AND REPRODUCTIVE CAPACITY.—Results of two years' work in measuring body size and testing the comparative reproductive rates of 31 aphid lines indicated strongly that a definite relationship existed between them. Using the mean values secured in experiment 1 of 1942, and the measurements for body length and width, correlation coefficients were computed for (1) reproductive rate and length, and (2) reproductive rate and width. The "r" values were .935 and .667, respectively, both highly significant as determined through use of "Student's" t-test.

The highly significant character of the positive "r" values indicates that a straight-line relationship exists between aphid size and rate of reproduction. This relationship is of value in isolating aphid lines of varying virulence from heterogeneous collections. Individuals belonging to highly virulent races may be segregated readily from aphids of the less virulent races on the basis of size differences alone, particularly if selections are made among 5th instar insects.

DISCUSSION.—The 1941 results expressed photographically in figure 1 indicate that O41, A41, W41-1 and V41 are more injurious to their host plants than the other lines. Measurements show O41, A41 and W41-1 to be significantly longer than all other lines, table 2. The 3 lines did not vary significantly in width, but as a group were significantly wider than all except K41 and U41. The CM41 line was distinctly smallest, the differences being significant in all comparisons for both length and width. With regard to comparative reproductive rates, O41, A41, and W41-1 produced greater numbers of progeny than all other lines, the differences being highly significant. Numbers of young produced by O41 and A41 did not vary significantly on any of the three varieties. W41-1, however, produced significantly fewer young than A41 on Perfection and Onward, than O41 on Pride. V41, ranking fourth in reproductive capacity, produced significantly greater numbers of young than W41-2 on all varieties. W41-2, in turn, produced greater numbers of young than U41, K41, NJ41 and CM41, the differences being significant in 10 of 12 comparisons over the three varieties. U41, K41, NJ41, and CM41 did not vary significantly among themselves on any of the three varieties.

In table 5, the five less virulent lines, W41-2, CM41, U41, NJ41 and K41 behaved consistently with respect to added resistance of the host plants, producing significantly greater numbers of young on Perfection than on Pride, and more on Pride than on Onward. With reference to O41, A41, V41, and W41-1 no significant difference was evident between numbers of young produced on Pride and Onward. These two varieties are nearly equal in resistance, the slight difference between them having no appreciable effect on the virulent lines. The difference in aphid resistance between Perfection and Pride, being greater than that between Pride and Onward, exerted sufficient influence on the virulent lines to cause a significant difference in the progeny produced by A41, V41, and W41-1. The most virulent line, O41, did not vary significantly. The wide range in aphid resistance between Perfection and Onward, representing almost the extremes of the known aphid resistance-susceptibility scale was great enough to cause a significant difference in the reproductive rates of all four virulent lines. It must be concluded, therefore, that the nine aphid lines did not behave consistently with respect to added resistance, and that it is the reaction of the four most virulent aphids which is out of line.

In the 1942 data on body length, O42 is similar to M42, and ND42 to A42-1. O42 and M42, however, are significantly longer than ND42 and A42-1, and all four of these lines are significantly longer than the eight remaining lines except U42, which is similar to A42-1. CM42-1 is significantly shorter than all other lines. The lines U42, NJ42, W42-1, CA42, K42, V42, and Ky42 form an orderly series of decreasing size in the order named. With one exception, any line picked at random is similar to the next two named but significantly longer than subsequent lines. In the measurements for body width, the arrangement is not so orderly. O42, longest of the group, is also widest, but not significantly more so than U42. The lines O42, U42, M42, K42, W42-1, A42-1, NJ42-1, and ND42 form a loosely knit group which is significantly wider than

V42, Ky42-1, CA42, and CM42-1. Within the large group U42, M42, K42, and W42-1 form a similar subgroup and A42-1, NJ42-1, and ND42 another. The two California lines rank last in body width.

Results of experiments 1 to 3 of the 1942 tests of comparative virulence show that lines O42, M42, A42-1, and ND42 produced greatest numbers of progeny, the difference between them and the other eight lines being clear-cut and highly significant. Of the four lines, O42 is similar to M42, and A42-1 to ND42. On the susceptible Perfection variety, these 2 pairs of lines varied significantly; on Pride all were similar; on Onward, ND42 was significantly different from O42 and M42. In experiments 4 to 6, A42-2 (sister line to A42-1), O42, M42, and ND42 were used as virulent checks. The response of these four lines was exactly identical with that of experiments 1 to 3—with relation to other lines tested as well as with the many interrelations among themselves. On the basis of this clear-cut repetition of results, it must be assumed that A42-1, A42-2 and ND42 are actually different from O42 and M42, the difference, as measured by numbers of progeny produced, being evident on the aphid-susceptible Perfection variety but masked by the added resistance of the Pride and Onward varieties. Examination of the body size data supports this view, since here O42 and M42 are found to be significantly longer and wider than A42-1 and ND42 in all comparisons.

With respect to the remaining eight lines tested in the 1942 experiments 1 to 3, K42 appears to have greatest virulence, since its reproductive rate was significantly greater than the others in 15 of 21 possible comparisons, and greater but not significantly so in 18 of 21 cases. V42 appears to be of extremely low virulence, producing smaller numbers of progeny than all other lines, the differences being significant in 17 of 21 comparisons. The six other lines varied significantly among themselves within each test, but the variation was inconsistent, hence further subdivision of the group appeared unwarranted. With respect to the Virginia collections V41 was highly virulent, whereas V42 was non-virulent, indicating that two biological races of the aphid are present in Virginia.

The information on relative size and reproductive rates of the 31 aphid lines offers fairly conclusive evidence that the pea aphid species is, in reality, a species-complex, composed of many biotypes. On the basis of the data gathered on comparative injury to host plants, body size and reproductive rates, the aphid lines are tentatively assigned to five biological races[1] as follows:

Race 1 (Highest virulence) O41, A41, W41-1, O42, M42

Race 2 (High virulence) V41, A42-1, A42-2, ND42

Race 3 (Intermediate virulence) W41-2, K42

Race 4 (Low virulence) U41, K41, NJ41, CM41, CM42-1, CM42-2(?), CA42, Ky42-1, Ky42-2, Ky42-3, NJ42-1, NJ42-2, U42, W42-1, W42-2, W42-3, W42-4, W42-5, W42-6

Race 5 (Lowest virulence) V42, CM42-2(?)

There is some question regarding the correct status of CM42-2. This line was tested in experiment 4 of 1942 with six members of Race 4. These six lines did not vary significantly among themselves, but all were significantly more virulent than CM42-2. On this basis alone, CM42-2 should be assigned to Race 5. However, it did not vary significantly from the six lines when tested on Pride and Onward. Its exact status, therefore, remains obscure.

In comparing results of the 1941 and 1942 tests it should be noted that the highly virulent W41-1 line was not recovered in the 1942 Wisconsin collections. Similarly, the virulent V41 line was not present in the 1942 collection. This strongly indicates that in these two cases, at least, more than one biological race is present in these areas.[2]

GENETIC AND GEOGRAPHIC ASPECTS OF THE RACE PROBLEM.[3]—Under favorable

[1] In this paper the terms "biotype" and "biological race" are used synonymously. Both denote an aphid line or group of lines which vary consistently and significantly from other lines in the quantitative characters studied, namely, body size and reproductive rate.

[2] During the winter of 1943–44 a random collection of aphids was made from vetch in the Milpitas, Calif. area. Subsequent testing of 6 parthenogenetic pure lines isolated from the collection revealed that 3 of the lines were members of virulent Race 1, the remaining 3 belonging to Race 4.

[3] The discussion of aphid genetics is based upon information secured from reliable textbooks of genetics under those sections devoted to the genetics of plant lice in general. The writer has been unable to find any reference to the genetics of *M. pisi* in the literature at his disposal. There is no reason to believe, however, that the basic principles of genetics in the pea aphid are different from that of other closely related aphids.

temperature and food conditions aphids reproduce parthenogenetically. The young are females, and arise from unreduced diploid eggs. This method of reproduction may continue indefinitely in mild climates. In more rigorous climates, however, diploid sexual forms are produced when temperature and food conditions become less congenial with the approach of winter. Normal meiosis takes place in these sexuales resulting in the production of haploid sperm and eggs. The eggs are fertilized normally, and from them diploid stem mothers arise the following spring. The stem mothers presumably are heterozygous, since the odds are slight that their parents were homozygous, as will be shown later. These stem mothers are true F_1 individuals, but since they reproduce parthenogenetically, no segregation occurs among their progeny (Ewing 1916). The progeny remain, therefore, genetically similar to the stem mothers, *i.e.*, homogeneous and heterozygous. Thus parthenogenetic pure lines are established and maintained for several generations during the summer, producing a great population of aphids genetically identical to the original stem mothers. Segregation, long delayed by the intervention of several asexual generations, takes place with the meiotic development of sperm and eggs in the sexuales. The number of kinds of eggs and sperm produced is limited only by the extent of genetic variation between the sexual parents of the previous year and by the elements of chance involved in the mechanics of segregation.

These genetic relationships are interesting when viewed from the standpoint of aphid distribution over the United States. Davis (1915) states that in the latitude of LaFayette, Indiana, the insect overwinters both as living viviparous females and as eggs, and in the latitude of Tennessee, sexual forms are rare, the insect overwintering as living viviparous forms. At the latitude of Norfolk, Virginia, Smith (1916) was unable to find oviparous females or eggs, and concluded that the insect passed the winter as mature viviparous females. Campbell reports that the only sexual forms encountered in his work in California were collected in the Antelope valley where winter temperatures approach zero. In three years of pea aphid investigation the writer has found no indigenous sexual forms at the latitude of San Jose, California. Stocks received from Corvallis, Oregon, 500 miles north of San Jose, contained sexual forms in the 1941 and 1942 collections. Consequently it may be assumed that in the wide band about the United States, extending from Virginia on the east coast to northern California on the west coast, and embracing the milder regions of Arizona, New Mexico, Texas, and other points east and south of Arkansas, aphid reproduction is maintained asexually from year to year. In this area parthenogenetic pure lines of varying virulence may exist and be maintained indefinitely without change or loss of identity through genetic intermixture. In areas to the north having a more rigorous climate the aphid must rely upon sexually produced eggs to bridge the freezing winter months. In these areas the separate identity of parthonegenetic pure lines established in the spring is lost with freezing of the last viviparous forms in the fall. Only the gametogenetic eggs of the oviparous aphids survive. Segregation, normally associated with the production of eggs and sperm, together with the union of heterozygous gametes during fertilization produce great numbers of genetically different stem mothers the following spring. And since each stem mother is the progenitor of a genetically homogeneous parthenogenetic line, variation among aphid lines in the northern states must be considerable.

In this paper, the 31 lines involved were studied on a purely quantitative basis, since feeding injury, size, and reproductive rate are all quantitative characters. The close relationship of size and virulence indicates that these two characters are quantitatively inherited, and that the difference between virulent and non-virulent aphids may be due to variation in the number of factors for size or vigor in the different genotypes.

There is no doubt but that these lines vary in other respects. Frequent observations have revealed considerable variation in developmental rates, color, resistance to disease, and in instinctive traits such as the degree of tenacity with which the aphids cling to the host plants when disturbed. With regard to color difference, the U41 line was conspicuous for its dark green pigment under all conditions of 1941.

Discovery of the multi-racial character

of the pea aphid may help to answer several questions which have confused entomologists for some time. Wide variations frequently encountered in the efficacy of contact insecticides in various areas or in the same area from year to year may be due to different aphid races or to different proportions of vigorous and nonvigorous aphids in the total population.

The cause of "spotting," *i.e.* small spots or areas showing particularly heavy damage in fields but lightly infested otherwise, has never been successfully solved, although theories involving soil types, wind currents, and temperature gradients, among others, have been advanced. These spots may indicate the infestation and consequent spread of a virulent aphid line in a field generally infested with less virulent lines. This theory is not impossible in view of the differential injury shown in figure 1.

The presence of more than one race in the same area may explain, weather conditions considered, why aphid damage is so variable from field to field of the same pea variety. "Bad aphid years" and "good aphid years" may bear a like interpretation.

The influence of the aphid race studies on future pea aphid research is paramount. Entomologists concerned with insecticide research will be interested in determining which race or race complex is involved in their tests as well as with those involved in the published results of co-workers. The role of the pea aphid as a vector of numerous plant diseases should be reexamined to determine whether the races differ in their ability to transmit specific pathogens. This is particularly true with the virus diseases.

SUMMARY.—During 1941 and 1942 aphid collections were received from 12 widely separated pea growing areas of the Nation and tested under uniform greenhouse conditions at Milpitas, California, to determine whether more than one biological race of the insect is present in the United States. Experiments involving comparative feeding injury, body size, and rates of reproduction indicate that the pea aphid species is a species-complex, composed of many races. All data obtained were subjected to appropriate statistical analyses, and on this basis the 31 aphid lines tested were tentatively assigned to five separate biological races.

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Experimental Use of Gas Condensate for the Prevention of Fly Breeding

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Gas condensate is a by-product resulting from the manufacture of cooking and heating gas by the carbonization of coal. Most commercial gas plants produce a light caustic fraction of about the viscosity of fuel oil, and in addition a heavier, dehydrated coal-tar fraction. Other plants do not separate these fractions, but obtain instead a watery sludge, which is a waste product. The heavy coal-tar fraction is readily soluble in the lighter material, and a mixture of the two contains tar, ammonia, a residue of heavy oil, sulfur, carbon disulfide, and benzene, toluene, anthracene, and other coal-tar products, and is very toxic to fly larvae, as is also the light fraction when used alone. It has been employed in Sarasota, Fla., as a wood preservative and treatment to prevent termites, and at Tallahassee, Fla., as a mosquito larvicide. Its use in these instances was very limited, and no other previous insecticidal applications have been noted.

This condensate is obtainable from many small plants, where facilities are not available for refining, and normally sells for about 6 cents per gallon at the plant. Its low cost, availability, and toxic properties are factors favorable to its use as an insecticide where a material of this nature is indicated. This article is to call attention to gas condensate as a potentially useful insecticide, rather than a recommendation for its use in specific instances.

The tests presented in this paper were conducted on bay grass (Dove & Simmons 1942), on peanut litter infested with stableflies (Simmons & Dove 1941), and on celery strippings infested with both stableflies and houseflies (Simmons & Dove 1942).

Mortality of Larvae and Pupae in Treated Media.—Tests with gas condensate on bay grass involved the treatment of about 19 miles of tidal drift consisting of a mixture of *Halodule wrightii* Aschers, *Thalassia testudinum* Koenig & Sims, and *Cymodocea manatorum* Aschers. The grass deposits averaged about 44 inches in width and 11 inches in depth and were well infested with all stages of stablefly larvae. Most of it was located above the water line on the shores of St. George Sound, Franklin County, Fla. In the majority of the tests the lighter fraction of gas condensate diluted with an equal quantity of No. 2 fuel oil was used, and this was applied with a power sprayer operating at 650 pounds' machine pressure. A total of 5620 gallons of material were used, or at the rate of 296 gallons per mile of grass treated, which is considerably less than the dosage of creosote usually employed for comparable material. Examinations of treated grass showed the mortality to be essentially 100 per cent in well-treated drifts. In addition to these general observations, more detailed tests were conducted as represented below.

On September 19, 1941, heavily infested mixed bay grasses in piles measuring 5 by 5 by 1 ft., located above high-tide mark, were well sprayed with equal parts of light gas condensate and No. 2 fuel oil, and were caged. Observations were made daily for 17 days after treatment, and no flies emerged, which indicated a complete kill. An untreated check plot of only 6 cubic feet of grass produced 231 adult stableflies over the same period.

At the same time 16 cubic feet of heavily infested, mixed bay grasses measuring 4 by 4 by 1 ft. were piled above high-tide mark and sprayed with the same materials from a power sprayer. Observations were made daily for 17 days, and no flies emerged. An untreated check plot produced 356 adult stableflies, or the equivalent of 22.25 flies per cubic foot of grass.

Light gas condensate is also effective in destroying all immature stages of the stablefly breeding in peanut litter. Numerous tests were made by spraying litter with a power sprayer, and the mortality was in the aggregate over 99 per cent. Table 1 is representative of the results obtained.

The lowest relative emergence occurred in tests where the heaviest applications of condensate were used. It is not considered essential, however, that this amount be

used, since flies emerged at the rate of only one per 2.56 cu. ft. of material receiving only 0.11 gallon of spray per cu. ft. In no instance did treated litter become reinfested. Areas where peanut litter was treated with light gas condensate were cultivated the following summer, and gross observations did not reveal any adverse effect on plant growth. Gas condensate is evidently effective in controlling the stablefly breeding in peanut litter, but it is more satisfactory and more economical to plow the litter under immediately after harvest, before it becomes infested, as described by Simmons & Dove (1941).

Table 1.—Results obtained in destruction of stablefly stages from treating peanut litter with light gas condensate, winter of 1941–42. Panama City, Fla.

Application Rate	Application Pressure	Flies Emerging from Litter	
		Treated	Untreated
Gal. per Cu. Ft.	*Lbs.*	*Number per Cu. Ft.*	
0.433	700	0.0	532.0
.213	650	.42	8.0
.130	400	.61	30.6
.166	400	1.77	127.5
.111	400	.39	127.5
.305	400	.05	127.5
.226	?	.54	158.8

Several tests made to determine the value of light gas condensate for treating infested manure showed that the breeding of houseflies in this medium could be effectively controlled, if adequate penetration by the spray was obtained.

On May 10, 1941, a plot of 78 cubic feet of celery strippings, 31 days old and heavily infested with third-stage larvae of both stableflies and houseflies, was sprayed at Sarasota, Fla., with 22 gallons of undiluted gas condensate. The condensate was a mixture of the light and heavy fractions containing about 40 per cent of the latter, and was applied with a power sprayer operating at 250 pounds pressure. Subsequent examinations showed a larval mortality of about 95 per cent, and the specimens remaining alive were in areas that had not been well treated. A 6 by 6 ft. cage kept over a portion of the treated litter for 4 days subsequent to treatment captured 136 stableflies and 34 houseflies, whereas a check cage captured 490 stableflies and 175 houseflies. Examinations indicate that the emergence from the treated litter was from pupae in poorly treated areas. Where only a surface application was made to infested litter the results were not satisfactory, and this was true of creosote sprays also.

Another test was conducted utilizing 72 cubic feet of strippings 16 days old heavily infested with both larvae and pupae of the stablefly. This was sprayed from a power sprayer with 55 gallons of a 10-per cent solution of the mixed condensate. A 100-per cent larval kill resulted from this treatment, but from the pupae collected 3 days after treatment 19.1 per cent emergence occurred. Some of the pupae were collected from lightly treated areas, and in these areas a light reinfestation of houseflies also occurred.

With violent agitation and ejection under high pressure the condensate may be sprayed as a mixture with water. Various dilutions of condensate, both in oil and in water, were tested against the stablefly and the housefly breeding in celery waste. Complete larval kills were obtained with as little as 10 per cent of condensate in No. 2 fuel oil, and with 20 per cent of condensate in water, where thorough penetration was obtained. The average dosage in the tests conducted was approximately 0.6 gallon of spray per cubic foot of medium; however, complete larval kills were obtained in shallow piles of waste with as little as 0.15 gallon per cubic foot. On the other hand, only partial kills of larvae resulted with much heavier dosages where spraying was not thorough and some of the medium received only a very light application.

Improperly treated celery strippings are more subject to reinfestation by houseflies than treated peanut litter or bay grass is to reinfestation by stableflies. This is due to the extreme attractiveness of the putrefying celery, and to the great dilution of the insecticide by the large quantity of water given off during decay of the waste.

In general these tests indicate that the immature states of both the stablefly and the housefly are effectively destroyed in a medium which is well treated with gas condensate.

PERSISTENCE OF THE INSECTICIDE IN TREATED MEDIA.—On May 23, 1941, green, uninfested celery strippings were treated, at Manatee, Fla., with 10.5 gallons of undiluted gas condensate, to prevent fly breeding. The condensate con-

sisted of about 60 per cent light and 40 per cent heavy fractions, and was applied with a sprinkling can throughout 125 cubic feet of the litter during the process of piling. Examination of this litter on June 16 showed no maggots or pupae, although sufficient moisture was present to breed flies, while untreated litter was infested with both stableflies and houseflies.

A similar test with diluted condensate was conducted in the same manner by treating 80 cubic feet of green, uninfested strippings with 7.5 gallons of 10 per cent of the condensate mix in No. 2 fuel oil. The material treated was examined on June 16 and no stable fly larvae or pupae were found but a few housefly larvae were present in lightly treated areas. In both these tests the litter was still well impregnated when examined 24 days after treatment.

In the course of normal control work approximately 19 miles of tide drifts of both uninfested and infested bay grass was treated with 5620 gallons of light gas condensate and No. 2 fuel oil in equal parts. Treatment was given in August and September 1941 from a power sprayer operating at about 600 pounds pressure. Constant observations were made to determine the permanence of the condensate under tidal action, and to determine its efficiency in preventing infestations of stableflies in grass that had been once well treated.

Under favorable conditions light gas condensate remains in the grass in fair quantity for about 2 weeks, but in the present instance much of it was lost by volatilization, and when rough tides or hard rains occurred just subsequent to treatment much of the light condensate was removed, and in one such instance very light breeding was found 16 days after treatment. Stations set up for special tests on the persistence of the treatment confirmed the results of the observations made over the larger area.

One-tenth mile of mixed bay grass was treated on September 19 with 100 gallons of equal parts of light gas condensate and bay water. This was subjected to both rains and tidal inundation, and by October 4 most of the condensate had been removed, but only an occasional larva was found in the treated grass.

A mixture of the light and heavy condensate was not used on bay grass, but the addition of the heavy fraction would raise the viscosity and seemingly should reduce volatilization, and such a material might be more satisfactory.

CONCLUSIONS.—From the preceding data it is concluded that gas condensate can be effectively utilized as an insecticide for the destruction of the immature stages of stableflies and houseflies breeding in certain types of decaying vegetable matter. It is indicated that other species of fly larvae present are also destroyed. The lighter fraction of gas condensate is quite volatile, and also may be leached out by severe tidal action. It is not at present recommended as a substitute for creosote for treating infested bay grass if the latter is available. The volatile nature of the light material is thought to be a favorable factor if the material is used to treat peanut litter on tillable soil.

It is suggested that the condensate might prove of use in certain types of operations for mosquito and sand fly control. When impregnated sawdust was distributed on water a good spread and surface film of the condensate was obtained.

SUMMARY.—Gas condensate is a by-product resulting from the manufacture of cooking and heating gas. Some plants produce both a light and a heavy fraction. The light fraction combined with No. 2 fuel oil, or a mixture of both fractions, is shown to be very toxic to the immature stages of stableflies and houseflies, and its use is suggested, in certain instances, as a cheap method of control of these pests.—11-8-44.

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Properties of Petroleum Oils in Relation to Toxicity to Potato Tuber Moth Larvae[1]

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The experience of the investigators who have attempted to correlate the physical and chemical properties of petroleum oils with their insecticidal action has shown that certain properties that make for increased effectiveness in combating one insect pest may be of no value or may actually reduce the effectiveness of the oil against insects of another species. This merely shows that oils produce their lethal effects in different ways with different species of insects. For instance, an oil that kills one insect by virtue of its toxicity may not be the best oil to use against another insect that is killed by suffocation and is, for physical or other reasons, not susceptible to toxic action of the oil. An oil that is highly effective against one insect because of its high volatility or penetrativity may be useless against an insect that is well protected against oil penetration by its derm or armor, or against an insect such as the California red scale, which can expel light oils from its spiracles (de Ong *et al.* 1927). The latter, however, may be effectively combated with a less volatile, more viscous oil.

Many examples could be cited to show how all the principal properties of spray oil that have been listed by entomologists as having a relation to insecticidal effectiveness—namely, viscosity, distillation range, volatility, unsulfonated residue, chemical composition, and others—actually have a different relation to insecticidal effectiveness with different insect species. Nevertheless, facts that may be discovered with regard to the insecticidal action of an oil on any one insect species are a contribution to the growing fund of knowledge on the general question of how oils kill.

The species selected as test insect for the present investigation was the larval form of the potato tuber moth, *Gnorimoschema operculella* (Zell.), at the stage in which it emerges from the potato in preparation for pupation. The mass production of *Macrocentrus ancylivorus* Roh. for the parasitization of the oriental fruit moth, *Grapholitha molesta* (Busck), as carried out at the University of California Citrus Experiment Station (Finney *et al.* 1944), has involved the rearing of thousands of larvae of the potato tuber moth daily. The writer has taken advantage of the steady supply of larvae to work out a method of using them as test insects in evaluating the insecticidal effectiveness of oil solutions.

POTATO TUBER MOTH LARVAE AS TEST INSECTS.—The potato tuber moth larvae were chosen for the experimental work described in the present paper, not only because of their availability in connection with the parasite production work, but also because they appeared to be admirably suited for use as test insects: They are easily reared in potatoes, in large numbers and with very little space and equipment, as many as 70 or 80 larvae being removed from a single potato; they can be moved about with forceps, apparently without injury; they respond to stimulation by means of a dissecting needle; and they survive long enough in petroleum oils and oil solutions to make possible accurate determinations, with sufficiently large numbers of larvae, of differences in the insecticidal effectiveness of various solutions.

Procedure.—According to the rearing method being used at this station (Finney *et al.* 1944), the development of the potato tuber moth larvae takes place in a room held at a temperature of about 80° F. and a relative humidity of about 40 per cent. A rapid circulation of air is maintained about the stacks of trays holding the infested potatoes. Since it was found that larvae reared in mature potatoes died more rapidly, when wet with oil, than those reared in immature potatoes, the potatoes used in the rearing of the larvae for the experiments reported in the present paper were immature.

At the time the larvae are emerging from the potatoes for pupation, they may be removed for use as test insects. Since the potatoes in a given group of trays are

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infested on the same day, the larvae removed at any one time are all of the same age; moreover, they have been reared under identical conditions of temperature and humidity and food substance. The larvae may be taken from the surfaces of the potatoes, or the soft and thoroughly riddled potatoes may be easily broken open and the larvae removed from within, usually from very near the surface.

In the experiments reported in the present paper, the differences in insecticidal effectiveness of the various oil solutions are based on the period required for 50 per cent of the larvae to become unable to respond to stimulation by a dissecting needle. It was found that accurate determinations of small differences in toxicity could be made with only 50 larvae per test, divided into five lots of 10 larvae each.

A disk of paper toweling was placed at the bottom of each of the five 100-ml. beakers used in a test, and a 1-ml. portion of the oil was poured into the beaker. The larvae, which were then placed in the beakers, became thoroughly wetted or covered with an oil film as soon as they came in contact with the oily paper. The number of minutes required for the death (or complete immobility) of the first 5 out of each lot of 10 larvae was recorded. For convenience, this is termed the median lethal period (M.L.P.).

Determination of Mortality.—When the larvae are being examined for determination of mortality, bodily movements may at first be noticed in some or all of the individuals; if not, movement may, in the early stages of the treatment, be induced by merely touching them with a dissecting needle. As the voluntary or induced movements become more feeble, more drastic prodding may be necessary to cause body movement. When 5 out of the 10 larvae in a lot no longer respond to prodding, the test is consummated, as far as that lot is concerned.

In recording the data for the experiments described in this paper, mimeographed record sheets were used. On these, the number of larvae not responding to stimulation with a dissecting needle, and the time of day to the closest quarter of an hour, could be conveniently recorded by writing the number of these larvae in the appropriate square for the time of day the observation was made. The median lethal period (M.L.P.) was calculated by subtracting the starting time from the time at which 5 larvae out of 10 failed to respond to stimulation.

When potato tuber moth larvae that had been immersed for several hours in kerosene stained with oil-soluble red dye were dissected, it was found that the kerosene had penetrated the tracheal system but had not entered the digestive system in any discernible amounts. Therefore, it was assumed that the death of the larvae was not hastened by ingestion of the oil. This belief was further strengthened by the observation that the larvae lived much longer when completely immersed in oil than when placed on blotting paper immediately after immersion, to draw away the excess oil. In one experiment made at 80° F., the larvae from which excess oil was removed lived on the average only 42.7 per cent as long as those which remained immersed in oil.

These observations are in accord with results obtained in tests with the California red scale, *Aonidiella aurantii* (Mask.). When adult female red scales were placed on microscope slides and wet with light-medium-grade spray oil, the excess oil then being drawn away by means of a blotter, very few individuals were found to live as long as 9 or 10 days, death being assumed to take place concurrently with cessation of movements of the pygidium. On the other hand, when adult female scales were allowed to remain in a beaker under several inches of oil, the majority of them were alive 10 days after immersion. Similar results were noted when scales were placed on a slide and covered with oil and then with a cover slip. Of 20 scales treated in this way, 2 appeared to be alive 40 days after being covered with oil.[1] Apparently, desiccation, oxidation, vaporization, or some other influence of the air increases the insecticidal action of the oil treatment. If the air is kept from the bodies of the insects, their period of survival is greatly increased.

[1] As far as the writer has been able to ascertain from the literature, the longest recorded period of survival of an insect immersed in oil is 17 days in the case of the Oestrid larva *Gastrophilus* (Wigglesworth 1939). de Ong *et al.* (1927) found that it required an average of about 7 days' immersion in highy refined mineral oil to kill mealybugs (*Phenacoccus colemani* Ehr.), when death was assumed to take place concurrently with cessation of all bodily movements, as determined by absence of response to stimulation with a dissecting needle. The last mealybug to die lived 16 days. On the other hand, the writer has noted that the adults of aphids, bettles, and ants, immersed in spray oil from 1 to 5 minutes, will become completely motionless, with no resumption of motility even though the oil is quickly removed from their bodies.

Potato tuber moth larvae kept in a vial through which a strong current of nitrogen was passed for 10 minutes became motionless after going through a brief period of high activity accompanied by a typical quivering of the body; but even when kept in the nitrogen as long as 20 hours, at 88° F., they recovered within a 10-minute period when again exposed to air, and resumed their normal activity apparently unimpaired. It required 36 hours or more in nitrogen before some of the larvae were found to be dead. When immersed in water for 20 hours at 88° F., 5 out of 10 larvae in one test and 6 out of 10 in another recovered when removed from the water and dried on blotting paper.

Potato tuber moth larvae become motionless much more rapidly in either nitrogen or water than they do in oil. But when they are taken out of the oil and the excess oil is removed from their bodies by means of a blotter, bodily movements are never again resumed and the larvae are apparently dead. It should be borne in mind, however, that the tracheal system remains filled with oil, and it may be that stupefaction is continued for this reason, just as it is in the case of larvae remaining in nitrogen or water. The oil-treated larvae, however, become discolored if left in the oil, or become dried and shriveled if exposed to the air, in much less time than is required for death in nitrogen or water. Thus it can be inferred that even the most highly refined oil is toxic to the larvae and kills them by virtue of its toxicity many hours before death could be assumed to have taken place by suffocation.

Effect of Temperature.—Since the larvae used in this experiment were covered with a heavy film of oil, relative humidity was eliminated as a variable factor capable of affecting results, except when kerosene was used. It was necessary, however, to make the various tests at a constant temperature.

The M.L.P. for larvae wet with light-medium oil in a room with a temperature of 70° F. was found to be an average of 2418 minutes. This was considered to be unnecessarily long. At higher temperatures the M.L.P. was greatly reduced. For example, when the larvae were wet with light-medium oil in a room held at 85° F., the M.L.P. was 172 minutes (Table 1, test 1). Thus the higher temperature greatly increases the speed with which the toxicity determinations can be made; yet the M.L.P. is sufficiently long to permit of accurate comparisons between treatments.

A Test of the Method with Oil-Toxicant Solutions Having a Wide Range of Insecticidal Effectiveness.—In table 1 are shown the results of an experiment in which the potato tuber moth larvae were used in the evaluation of oil-toxicant solutions. The data are typical of those obtained in repeated experiments. These

Table 1.—Period required for 50 per cent mortality (M.L.P.)[1] of potato tuber moth larvae wet with light-medium oil alone and with added toxicants. Temperature, 85° F.

Material	M.L.P., in Minutes					
	Test No.—1	2	3	4	5	Mean
1. Oil alone	150	210	170	150	180	172
2. Oil plus 1 per cent dinitro-o-cyclohexylphenol	6	7	6	7	6	6
3. Oil plus 1 per cent *Lethane 440*[2]	15	15	11	12	12	13
4. Oil plus 0.625 per cent derris extractives[3]	27	24	26	24	22	25
5. Oil plus 1 per cent nicotine	50	41	35	34	35	39
6. Oil plus 1 per cent *Thanite*[4]	45	45	40	30	40	40
7. Oil plus 0.1 per cent pyrethrins (5 per cent pyrethrum extract)	90	105	90	100	90	95
8. Oil plus 4 per cent DDT[5]	95	125	110	140	110	116
Significant difference at odds of 19:1						14.5

[1] Median lethal period.
[2] A proprietary mixture containing 50 per cent b-butoxy-b'-thiocyanodiethyl ether.
[3] Butyl phthalate solution containing 5 per cent derris extractives (30 per cent rotenone), used at a concentration of 1 part to 7 parts of oil.
[4] Fenchyl thiocynyl acetate.
[5] 2,2-bis-(p-chlorophenyl)-1,1,1-trichloroethane.

data are included, not as having any relation to the general subject of the paper, but as an example of the usefulness of the larvae as test insects with toxic solutions covering a wide range of insecticidal effectiveness.

Against the larvae, dinitro-o-cyclohexylphenol was found to be the most effective of the seven toxicants tested. However, the pyrethrum extract was used at a strength which resulted in a concentration of pyrethrins in the oil of only 0.1 per cent; this solution was therefore not directly comparable with the others. DDT,[1] which has recently gained world-wide attention because of its phenomenal effectiveness against some insects, was the least toxic of the compounds tested, even though used at a higher concentration than any of the other toxicants. The 4 per cent DDT was significantly less toxic than pyrethrins used at only one-fortieth as high a concentration. It was also found that 4 per cent diphenyltrichloroethane, synthesized in this laboratory by Francis A. Gunther, and differing from DDT in having two less chlorine atoms in the molecule, had no toxicity whatever against the potato tuber moth larvae.

In the experiments described above, made at a constant temperature of 85° F., the M.L.P. ranged from a mean of 6 minutes for oil plus 1 per cent dinitro-o-cyclohexylphenol to 172 minutes for oil alone, a difference of 14.5 minutes being significant at odds of 19:1.

[1] 2,2-bis-(-pchlorophenyl)-1,1,1-trichloroethane.

EFFECT OF DISTILLATION RANGE AND VISCOSITY OF OIL ON TOXICITY.—Table 2 shows the M.L.P. of potato tuber moth larvae wetted with three spray oils and with kerosene. The physical characteristics of these oils are indicated in the table. It will be noted that there is practically no difference in the mean M.L.P. with light and light-medium oils, despite the differences in distillation range and viscosity of the oils. The M.L.P. for the larvae wetted with heavy oil is numerically higher in both experiments and significantly higher in the experiment made at a room temperature of 70° F., but the unsulfonated residue for this oil is also higher. The M.L.P. for the larvae wet with kerosene, however, was much lower than that for the larvae wet with any of the three spray oils. It can therefore be concluded that the M.L.P. is not correlated with distillation range and viscosity until the very light petroleum fractions are reached.

Shafer (1911) concluded from his extensive and carefully conducted experiments that insects were killed with kerosene, not by plugging of the spiracles, but by absorption of the volatile portions of the kerosene into the insect tissues. He found that vapors from kerosene entered the tissues and caused their typical effects long before the kerosene, as such, had time to penetrate the chitin. The writer is aware, of course, that the kerosene used by Shafer was probably not so highly refined as the kerosene of today, but this would not invalidate the conclusions he

Table 2.—Period required for 50 per cent mortality (M.L.P.)[1] of potato tuber moth larvae wet with four oils of different degrees of heaviness, at different temperatures.

Oil	Unsulfonated Residue	Temperature (F.) for Distillation of 5%	Temperature (F.) for Distillation of 90%	Viscosity, at 100° F.[2]	Sp. Gr., 60/60° F.	Refractive Index, $n_D^{20°}$	M.L.P., in Minutes: Test 1	2	3	4	5	Mean
Room Temperature, 70° F.												
Light	92.0%	554°	688°	61	0.882	1.482	2490	2730	2190	2490	2370	2454
Light-medium	92.0	582°	693°	71	0.886	1.482	2190	2310	2730	2490	2370	2418
Heavy	94.4	622°	706°	94	0.889	1.482	2730	2790	2280	3150	2730	2736
Kerosene	97.0	344°	449°		0.800	1.448	984	1266	984	900	1122	1051
Significant difference at odds of 19:1												
Room Temperature, 86° F.												
Light	92.0%	554°	688°	61	0.882	1.482	198	297	180	171	215	212
Light-medium	92.0	582°	693°	71	0.885	1.482	210	210	198	228	204	210
Heavy	94.4	622°	706°	94	0.889	1.482	315	210	210	270	247	250
Kerosene	97.0	344°	449°		0.800	1.448	105	105	105	131	105	110
Significant difference at odds of 19:1												45.6

[1] Median lethal period.
[2] Saybolt Universal Viscosity at 100° F.

reached as to the influence of volatility.

Shafer noticed that the vapors of kerosene had an effect on the nervous system similar to that of pyrethrum and ether vapors. He found that vapors of kerosene, gasoline, carbon disulfide, creolin, benzol, xylene, turpentine, aniline oil, chloroform, ether, nicotine, pyrethrum, hydrocyanic acid gas, nitrogen, and hydrogen at first produced more or less excitement, then a period of uncertain movements, and finally, when used in larger amounts, anaesthesia or narcosis. Shafer (1911) states that the evidence seems to indicate that the vapors, after absorption into the insect body, become mainly effective through some tendency their presence exerts to prevent oxygen absorption by the tissues.

When the potato tuber moth larvae are immersed in 20 ml. of kerosene in 100-ml. beakers, at 85° F., sporadic body movements may be noticed for 30 minutes or more. The fact that these movements are much more frequent and more vigorous when the larvae are immersed in kerosene than when they are immersed in the usual spray oil, indicates a marked difference in physiologic effect of the two types of oil. In the kerosene, after the more vigorous body movements have ceased, the larvae undergo frequent periods of hardly perceptible body tremors, with occasionally a more violent quivering.

When completely immersed, the larvae live about as long in kerosene as in regular spray oil. No significant difference in M.L.P. could be found when the larvae were completely immersed in the two types of oil. The more rapid death of the larvae wet with kerosene, as shown in table 2, is apparently caused by the rapid volatilization of the kerosene on the paper toweling and on the bodies of the larvae, until the larvae finally have no excess kerosene on their bodies and have a dry appearance. As stated before, insects die more rapidly, according to the writer's experience, when covered with a thin film of oil than when covered with a thick film or when completely immersed in oil. If, by means of a blotter, the excess oil is removed from the larvae wet with the less volatile spray oil, they also die more rapidly than when they retain a thick film of oil on their bodies.

As the heaviness of petroleum oils is increased, the volatility decreases. Even when the larvae are merely wet with the oil, a point is reached at which volatility no longer is the prime factor influencing the death of the insects, and from that point on variations in volatility or in distillation range and viscosity of the oils do not result in corresponding variations in toxicity. Thus a "light" spray oil (76 per cent distilled at 636° F.) and a "heavy" spray oil (15 per cent distilled at 636° F.) are about equally toxic to potato tuber moth larvae at a given value of unsulfonated residue.

In dismissing viscosity as a factor influencing toxicity, it should nevertheless be borne in mind that the greater the viscosity of an oil, the greater the deposit of oil on the plant and, presumably, on the insect surfaces, and, consequently, the greater the insecticidal effectiveness of the spray. This has been shown repeatedly in both laboratory and field experiments at this station.

EFFECT OF PARAFFINICITY ON TOXICITY.—Chapman *et al.* (1944) have recently shown that at low dosages the control efficiency of paraffinic spray oils is superior to that of naphthenic spray oils when used against the San Jose scale, *Aspidiotus perniciosus* Comst. In carefully controlled laboratory experiments, Lindgren[1] found that a paraffinic type oil was more effective against the adult females of the California red scale, *Aonidiella aurantii* (Mask.), than a naphthenic type oil similar in all respects but viscosity. Paraffinic oils have lower viscosities than naphthenic oils of otherwise similar physical properties. In tests with oils of similar density and distillation range, Lindgren found that the sprays with paraffinic oils deposited less oil on the surfaces of the grapefruits used in the experiment than the sprays with naphthenic oils, presumably because of their lower viscosity. Despite the lower oil deposit, however, the paraffinic oils resulted in a higher percentage kill of scales than the naphthenic oils, when both were used at percentages resulting in less than 100 per cent kill.

Penny (1921), also, found the paraffinic base oils to be greatly superior to naphthenic base oils, when used against the eggs of the fruit tree leaf roller, *Archips argyrospila* (Wlk.), in California, and

[1] Dr. D. L. Lindgren. Data on file at the University of California Citrus Experiment Station, Riverside, California.

stated that G. M. List had a similar experience with the two types of oils in Colorado. Chapman *et al.* (1943) found that the greater the paraffinic character of an oil, the more efficient it is against the eggs of the oriental fruit moth (*Grapholitha molesta* [Busck]), the codling moth (*Carpocapsa pomonella* [L.]), and the eye-spotted budmoth (*Spilonota ocellana* [D. and S.]). The oils predominantly paraffinic in character were as much as ten times as effective as the naphthenic base oils.

On the other hand, Griffin *et al.* (1927), working with three paraffinic base oils and three naphthenic base oils, found no difference in their toxicity to the bean aphid, *Aphis rumicis* L. Swingle and Snapp (1931) found that petroleum oils of both naphthenic and paraffinic base, when used at 3 per cent concentration, were all uniformly highly effective against the San Jose scale. Likewise, in the present series of experiments, no significant difference in toxicity, as based on the M.L.P., could be found between paraffinic and naphthenic oils of the same or closely similar unsulfonated residue (Table 3).

EFFECT OF UNSULFONATED RESIDUE ON TOXICITY.—The effect of percentage of unsulfonated residue (U.R.) on the toxicity or insecticidal effectiveness of spray oils has long been a matter for discussion and controversy among entomologists. de Ong (1931), in experiments in which beetles (*Hippodamia convergens* Guerin) were immersed in oil, found that while it required an average of 268 seconds to kill beetles with an oil of 99.4 per cent U.R., the period decreased with each successive reduction in unsulfonated residue until an average of only 46.2 seconds was required at 90 per cent U.R. The oils were of the same physical character throughout.

These findings are in accord with those of the writer on the effect of unsulfonated residue on the toxicity of oil to potato tuber moth larvae, as determined by the period required for 50 per cent mortality (Table 3). With the two naphthenic base (Western) oils and the paraffinic base (Eastern) oil,[1] the only factors that appeared to be correlated with changes in toxicity were unsulfonated residue and the physical factors such as specific gravity and refractive index, which change with changes in unsulfonated residue. As can be seen from table 3, the lower the unsulfonated residue, the lower the M.L.P.

Table 3.—Period required for 50 per cent mortality (M.L.P.)[1] of potato tuber moth larvae wet with oils varying in percentage of unsulfonated residue, at different temperatures.

Oil	Unsulfonated Residue	Temperature (F.) for Distillation of 5%	Temperature (F.) for Distillation of 90%	Viscosity,[2] at 100° F.	Gr., 60/60° F.	Refractive Index, $n_D^{20°}$	M.L.P., in Minutes Test 1	Test 2	Test 3	Test 4	Test 5	Mean
Room Temperature, 75° F.												
Naphthenic Sample: (*group A*)												
1	98%	558°	725°	57	0.855	1.468	1507	1665	1665	1665	1800	1660
2	92	571°	695°	71	0.886	1.482	1665	1350	1515	1665	1565	1552
3	80	572°	703°	72	0.904	1.497	405	841	360	656	609	574
4	60	570°	698°	75	0.925	1.516	225	315	225	300	240	261
Significant difference at odds of 19:1												172
Room Temperature, 85° F.												
Naphthenic Sample: (*group A*)												
1	98	558°	725°	57	0.855	1.468	270	225	225	238	285	249
2	92	571°	695°	71	0.886	1.482	225	193	193	168	238	203
3	80	572°	703°	72	0.904	1.497	113	157	165	157	97	138
4	60	570°	698°	75	0.925	1.516	60	78	75	54	75	68
Naphthenic Sample: (*group B*)												
1	97	576°	713°	67	0.873	1.473	225	225	270	270	238	246
2	80	501°	709°	55	0.883	1.485	135	150	150	135	97	133
3	71	448°	705°	48	0.887	1.490	90	90	80	90	75	85
Paraffinic Sample:												
1	98	426°	735°	44	0.824	1.453	270	270	270	285	203	260
2	81	558°	724°	58	0.864	1.480	135	135	97	97	113	115
3	64	100°	721°	41	0.881	0.492	70	66	66	78	54	67
Significant difference at odds of 19:1												28.6

[1] Median lethal period.
[2] Saybolt Universal Viscosity, Seconds at 100° F.

[1] The napthenic base oils of group A (Table 3) were supplied by the Tide Water Associated Oil Company; the naphthenic base oils of group B, and the paraffinic base oils, were supplied by the California Spray Chemical Company.

This held true in the upper range of percentage of unsulfonated residue (Table 3, tests 1 and 2) as well as in the lower range. At 75° F. the mean M.L.P. of potato tuber moth larvae was 1660 minutes when they were immersed in an oil of 98 per cent U.R., and 261 minutes in an oil of 60 per cent U.R. At 85° F. the range in mean M.L.P. for naphthenic oil, group A, with a range of 98 to 60 per cent U.R., was 249 to 68 minutes; for naphthenic oil, group B, with a range of 97 to 71 per cent U.R., the M.L.P. ranged from 246 to 85 minutes; and for the paraffinic oil, with a range of 98 to 64 per cent U.R., the M.L.P. ranged from 260 to 67 minutes.

About the same differences in toxicity of high U.R. and low U.R. oils were found in less extensive experiments made at room temperatures with full-grown maggots of the housefly, *Musca domestica* L. For example, when housefly maggots were immersed in a heavy citrus spray oil (94 per cent U.R.), 5 out of 10 died in 195 minutes in one test, and 3 out of 10 died in 180 minutes in another. When the maggots were immersed in an oil of about the same distillation range but with 60 per cent U.R., all died in the first test, and 8 out of 10 in the second test.

Contrary to the above results Griffin *et al.* (1927) found unsulfonated residue to have no influence on the insecticidal effectiveness of spray oils used against *Aphis rumicis* L. Swingle and Snapp (1931) found that naphthenic and paraffinic base petroleum oils varying in unsulfonated residue from 0.0 to 68.8 per cent were all uniformly highly effective against the San Jose scale, *Aspidiotus perniciosus* Comst., when used at 3 per cent strength. However, the kill was so near 100 per cent with all the oils tested that the differences in insecticidal efficiency of the oils of different unsulfonated residue could not be determined from the data presented.

Ebeling (1932) concluded from orchard tests made against the California red scale, *Aonidiella aurantii* (Mask.), that spray oils varying in unsulfonated residue from 86 to 100 per cent were not significantly different in their insecticidal effectiveness. As the result of laboratory and field experiments with the camphor scale, *Pseudaonidia duplex* (Ckll.), in which the oils used ranged in unsulfonated residue from 77 to 94 per cent, Cressman (1936) concluded that "no evidence was found that the sulphonatable portions of the oils had any effect upon the insecticidal action when the other physical and chemical properties of the sprays were uniform."

It is to be expected that the more polar nature of the relatively active unsaturated hydrocarbons would increase the "tightness" of an oil emulsion and consequently reduce the amount of oil deposited by the spray upon striking a plant or insect surface. Making 10 measurements with each oil with a Cenco-du Noüy interfacial tensiometer at 23° C., the writer found the average interfacial tension of light-medium spray oils of varying percentages of unsulfonated residue, and water, to be as follows: at 92 per cent U.R., 31.4 dynes per centimeter; at 70 per cent, 23.7 dynes per centimeter; and at 60 per cent, 22.1 dynes per centimeter. Cressman's (1936) figures, from his laboratory spraying experiments, showed a decrease in deposit in each of four trials in which the unsulfonated residue of the oils was successively decreased from 94 to 67 per cent. The differences in oil deposit ranged only from 5 to 16 per cent, however, and it may be concluded from the evidence presented with regard to the influence of unsulfonated residue on the effectiveness of spray oils used against armored scale insects, that there is little if any effect on the toxicity of the oil attributable to the hydrocarbon compounds which are removed from the oil by sulfuric acid.

The above conclusion is verified by observations which the writer has made on the survival period of the California red scale immersed in spray oils of varying percentages of unsulfonated residue. The scales were considered dead when repeated observations with the aid of a microscope revealed no movements of the pygidium. Mature female scales were found to show feeble movements of the pygidium as long as 9 or 10 days after immersion in the oil, whether the oil was 60 or 98 per cent U.R. On the basis of observations of 40 individuals in each oil, the writer concluded that there was no important difference in the period of survival. However, no difference was found in the periods of survival of mature female red scale immersed in oil with added derris extractives (Ebeling and LaDue 1943), and it was concluded that the addition of derris ex-

tractives increases the effectiveness of the oil only against those individuals which have not received enough oil to plug their spiracles and kill them by suffocation. The death of the scales by suffocation when they are immersed in oil is assumed from the fact that they die more rapidly in an oxygen-free atmosphere than in oil. No sign of movement of the pygidium was observed after 7 days, when the scales were confined in nitrogen for 12 hours, even though the insects were left on the grapefruit which they infested.

The writer concludes that some insects, such as the California red scale, when immersed in oil, die of suffocation before either naturally occurring or introduced toxic ingredients in the oil have time to exert their lethal effect. This appears to be the case despite the long period required to kill the scales by suffocation. It is to be expected that this class of insects will survive in an oil of low unsulfonated residue as long as in an oil of high unsulfonated residue, even though the former would be expected to be the more toxic on the basis of its relatively higher chemical activity.

The experience with oils of varying percentages of unsulfonated residue, used against insect eggs, is similar to that mentioned in connection with their effect against larvae and adults. Spuler *et al.* (1931) state that oils of the same viscosity may vary as much as 48 per cent in unsulfonated residue without differing in their effectiveness against eggs of the codling moth, *Carpocapsa pomonella* L. According to Martin (1936), Austin, Jary, and Martin found that hydrocarbon oils were effective against the eggs of the capsid *Lygus pabulinus* L. only when containing above a certain percentage of saturated hydrocarbons; yet against the eggs of Aphididae and Psyllidae, according to Staniland *et al.* (1930), the saturated hydrocarbons are devoid of ovicidal properties. It is believed by the latter that the eggs of the capsid *Plesiocoris rugicollis* and the "winter moth" are killed chiefly by a stifling or smothering action of the oil film, but that the eggs of *Aphis* spp. and *Psylla mali* are killed by toxic action. It was necessary to use tar distillates against the last two: heavy medicinal paraffin oils would not prevent the hatching of eggs. Chapman *et al.* (1943) showed that in the case of both paraffinic and naphthenic type oils, those of higher percentage unsulfonated residue resulted in better kill of the eggs of the oriental fruit moth and the codling moth.

Martin (1936) suggests that oils used against insects or insect eggs killed by "stifling" action should contain the highest practicable percentage of saturated hydrocarbons, while those used against insects or insect eggs killed by chemical action, should contain aromatic hydrocarbons above a certain minimum. Apparently, no one has shown why oils high in saturated hydrocarbons are more effective than those of high aromatic or unsaturated hydrocarbon content against certain insect eggs. The relative persistence or oxygen permeability of the oil films may be the decisive factors in these cases as well as in those in which paraffinic oils are found to have greater insecticidal effectiveness than naphthenic oils. This possibility is now being investigated at this station.

SUMMARY.—Experiments were made with the larvae of the potato tuber moth, *Gnorimoschema operculella* (Zell.), to ascertain their value as test insects in the determination of the insecticidal effectiveness of oil solutions. It was found that accurate determinations of small differences in toxicity could be made with only 50 larvae per test, divided into five lots of 10 larvae each.

One-milliliter portions of oil were poured on disks of paper toweling placed at the bottoms of 100-ml. beakers. The larvae deposited on these oily disks became completely covered with an oil film. The period required for 50 per cent mortality (M.L.P.) of the larvae in each of the beakers was recorded. For practical purposes death was assumed to take place concurrently with the cessation of bodily movements of the larvae when they were prodded with a dissecting needle.

No oil was found in the intestinal tracts of larvae that had been immersed in stained oil for several hours. It was assumed, therefore, that the death of the larvae was not hastened by ingestion of the oil.

Data are presented to show the great differences in M.L.P. (median lethal period) obtainable with oil solutions of some common insecticides.

There appeared to be no relation between viscosity and distillation range of

the regular citrus spray oils and their toxicity to the potato tuber moth larvae, but kerosene, which has a much lower viscosity and distillation range than the spray oils and is much more volatile at the temperatures at which the experiments were made, was found to be more toxic than the latter. This was caused by the disappearance of excess kerosene from the bodies of the larvae, a condition found to be conducive to greater insecticidal effectiveness of oils. There was no significant difference in M.L.P. when the larvae were completely immersed in the two liquids.

No difference was found between the toxicity of naphthenic base (Western) oils and paraffinic base (Eastern) oil. With both the naphthenic and the paraffinic oils, the lower the percentage of unsulfonated residue, the greater was the toxicity of the oil to the potato tuber moth larvae. The unsaturated hydrocarbons were also found to increase the toxicity of spray oils to housefly larvae.

The possibility is suggested that the superiority of the paraffinic base oils to the naphthenic base oils, in their effectiveness against certain insects or insect eggs, may be due to the physical nature or oxygen permeability of the oil or oil film rather than to the toxicity per se of the oil; for when potato tuber moth larvae, which are very sensitive to changes in the toxicity of the oil, are immersed in oil or wetted with a great excess of oil, they survive as long in a naphthenic oil as in a paraffinic oil.

It appears from a review of the literature that, in relation to their effects on insects or insect eggs, the petroleum hydrocarbons removable from spray oil by treatment with sulfuric acid or by the SO_2 process (1) may increase insecticidal effectiveness, (2) may have apparently no effect because suffocation takes place before toxic action is possible, or (3) may actually reduce the effectiveness of the oil, presumably by an adverse effect on the physical nature of the oil film.

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Soil Treatments with Special Reference to Fumigation with D-D Mixture[1]

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The continued use of soil for the production of a single crop, without rotation, is generally recognized as a risky procedure, not to be considered as permanent agriculture. In old world countries, where organic matter is kept at a high level and rotation is practiced, the fertility of soil has been maintained, but in tropical or semi-tropical countries, the maintenance of a rich organic substrate is difficult, if not impossible, except in the most primitive forms of agriculture.

One reason for the gradual decline of productivity is the accumulation of deleterious species in the soil complex which is here defined as all those organisms, macro and micro, the activities of which, either singly or in combination affect plant growth. Possibly related to this phenomenon, and the specific reason for the entry of the writer into the problem of soil fumigation, was the evidence that pineapple plants grown in virgin soil were less susceptible to mealybug wilt. This was based on observations, not only in Hawaii but in many other pineapple growing areas throughout the world (Carter 1942). In Hawaii it has been observed occasionally when the revamping of old field margins has resulted in adding small sections of virgin land to the old field area, and in a few cases where chloropicrin fumigation had been used prior to planting, plants were more vigorous in ratoon and less susceptible to mealybug wilt, in spite of large mealybug populations, than was the case in older fields which had been cropped continuously to pineapples with only a fallow intercycle.

Quite apart from the question of susceptibility to mealybug wilt, in recent years it has become increasingly evident that in many pineapple growing areas in Hawaii, some sort of control over the steadily increasing pathogenicity of the soil complex was necessary if pineapple growing was to be considered permanent agriculture. The fumigation of soils with chloropicrin has been practiced to some extent and prior to the present study, chloropicrin was perhaps the only material which had shown promise. Its principal objections are its cost, and the difficulty of using it in the field. It has been shown to affect the nitrifying organisms in the soil (Tam & Clark 1943) and its use has resulted in considerable increase in yield (Johnson & Godfrey 1932). The studies reported on in this paper began in 1936 and have continued to date. A preliminary paper (Carter 1943) set forth the results with one new fumigant and the purpose of this paper is to present the supporting data in some detail, in addition to reporting negative results with a number of other compounds.

MATERIALS USED.—The first tests were with weed killers, it being supposed that at suitable concentrations, these materials which are generally low in cost, might serve a useful purpose. Two proprietary compounds were used, but the greatest emphasis was on the use of chlorinated compounds.[3] The complete list of materials used is given in table 1.

RESULTS WITH WEED KILLERS.—Ammonium sulfamate and sulfamic acid applied to the surface of the soil prior to planting resulted in severe depression of growth that was evident shortly after the plants started growth and continued until plant crop was harvested. No further tests were conducted.

Ammonium thiocyanate was first used in November 1936 when it was applied along with the ammonium sulphate as an under paper treatment. Planting followed immediately after treatment. Some toxic effects were noted the following spring when the leaf tips turned yellow for a length of two to three inches. By August of that same year (1937) this effect had disappeared. Plant crop and first ratoon yields from this experiment are summarized in table 2.

Considering the early toxic effect and the slightly improved yield in plant crop,

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[2] Acknowledgment is gratefully made to K. Ito for assistance in the heavy routine involved and for the statistical analysis and to C. T. Schmidt for the preparation of the boiling point fractions of D-D mixture.

[3] The chlorinated compounds were kindly furnished by the Shell Development Company of Emeryville, California.

Table 1.—List of materials used.

	Lbs. per Acre	See Table No.
Weed killers		
Ammonium thiocyanate	100, 250, 500, 1000	2
Ammonium sulfamate	100, 250, 500	
Sulfamic acid	100, 250, 500	
Organic Complexes		
Bagasse	10 and 20 tons	4
Filter press cake	10 and 20 tons	4
Cashew oil salts	500	
Proprietary Compounds		
Circle B	100, 200, 500	3, 4
Photo Sen Sin	50 gms per plot	5
Bromine Combinations		
10% and 20% Bromine in carbon tetrachloride	150	
20% Bromine in tetrachlorethane	150	
Chlorinated Compounds		
Allyl chloride	150	6, 7, 8
C_4 chlorides	100, 200, 300	5
2 Chloropropylene	121	
D-D mixture	150	6, 7, 8, 9, 10
Dichlorethyl ether	253	
Epichlorohydrin	100, 200	3
Glycerin dichlorohydrin	150	3
Methallyl chloride	150	6
Tetrachloropropyl ether	150	3
Chloropicrin	150	3, 4, 5, 6, 7, 8, 9
Alcohols		
Allyl alcohol	150, 200	3, 6, 7, 8
Allyl alcohol+Carbon tetrachloride	100 ea.	
Allly alcohol+Diesel oil	50 ea.	
Allyl alcohol+Tetrachlorethane	50+100	
Allyl alcohol+Carbon bisulphide	100 ea.	3
Allyl alcohol emulsion	150	3
Crotyl alcohol	150	3
Methallyl alcohol	150	6, 7, 8
Methyl vinyl carbinol	150	3

additional tests were set out in 1942. These tests included applications at the rate of 150 and 350 lb per acre with plantings delayed for one, two and three weeks after application and at the rate of 500 and 1000 lb per acre when the material was broadcast prior to the final plowing before planting. None of these experiments resulted in significant increases in yield.

Results with *Circle B* and *Photo Sen Sin*.—Improvement in plant growth following treatment of the soil with these materials has been claimed and both were tested, *Circle B* on the basis of the inclusion of an animal repellent oil in its composition and *Photo Sen Sin* on the basis of reports from tests on the mainland.

Circle B was hoed in to the soil prior to laying the paper, at the rates of 100, 200 and 500 lb per acre in one experiment, which also included a number of chlorinated compounds, and in another at 500 lb. per acre in comparison with organic materials and chlorinated compounds. The results of these tests are to be found in tables 3 and 4 and are clearly without significance.

Photo Sen Sin, a fluorescent dye, was applied to the soil prior to planting at the rate of one gm per plant in an experiment which included C4 chlorides and chloropicrin. The results are in table 5 and although no significant difference between the check and any treatment but chloropicrin is shown, nevertheless, the position of *Photo Sen Sin* indicates that this material might be worthy of additional trial.

Table 2.—Summary of plant crop and first ratoon yields following treatment of the soil before planting with ammonium thiocyanate.

Treatment	Plant Crop		First Ratoon	
	No. of Fruits Weighed	Average Weight	No. of Fruits Weighed	Average Weight
Check	2285	5.01	2832	3.49
Ammonium thiocyanate 100 lb/A	826	5.18	1533	3.49
Ammonium thiocyanate 200 lb/A	676	5.21	1189	3.55

Table 3.—Tests with chlorinated compounds and *Circle B*. Summary of plant crop and ratoon yields.

Treatment		Mean Fruit Weight in Pounds		
Material	Dosage lb/A	Plant Crop 1943	1st Ratoon 1944	Cycle 1943–44
Allyl alcohol	200	3.66	3.31	3.48
Allyl alcohol+CS_2	100 ea	3.66	3.13	3.40
Allyl alcohol emulsion	150	3.79**	3.26	3.52
Check		3.53	3.33	3.43
Chloropicrin	150	4.25**	3.12	3.69*
Circle B	100	3.70	3.41	3.55
Circle B	200	3.59	3.35	3.47
Circle B	500	3.47	3.43	3.45
Crotyl alcohol	150	3.51	3.33	3.42
Epichlorohydrin	100	3.53	3.34	3.39
Epichlorohydrin	200	3.67	3.15	3.41
Glycerin dichlorohydrin	150	3.54	3.19	3.36
Methyl vinyl carbinol	150	3.69	3.33	3.51
Tetrachloropropyl ether	150	3.46	3.01	3.24

* Significant over check for odds of 19:1.
** Significant over check for odds of 99:1.

Table 4.—Tests comparing chlorinated compounds, organic matter and *Circle B*

Treatment	Dosage per Acre	Mean Fruit Weight in Lbs.		Cycle
		Plant crop	First ratoon*	
Chloropicrin	150 lb	4.53	2.57	7.10
Allyl alcohol	200 lb	4.45	2.71	7.16
Allyl alcohol+CS_2	100 lb ea	4.29	2.32	6.61
Bagasse	10 tons	4.49	2.68	7.17
Bagasse	20 tons	4.51	2.74	7.25
Circle B	500 lb	4.12	2.44	6.56
Filter cake	10 tons	4.49	2.58	7.07
Filter cake	20 tons	4.15	2.50	6.65
Check		4.19	2.47	6.66

* Not significant at odds of 19:1.

Table 5.—Test comparing chloropicrin, *Photo Sen Sin* and a mixture of C_4 chlorides. Summary of plant crop yields.

Treatment	Dosage lb/A	No. of Replications	Total No. of Fruits Weighed	Mean Fruit Wt. (lb)	Dif. from Prev. Value (lb)
Chloropicrin	150	3	323	4.40	
Photo Sen Sin	50[1]	3	322	3.98	0.42
C_4 chlorides	300	3	348	3.81	0.17
Check	None	18	1658	3.70	0.11
C_4 chlorides	200	3	334	3.59	0.11
C_4 chlorides	100	3	313	3.43	0.16

[1] Grams per plot.
Critical difference necessary for significance at odds of 19 to 1:
Comparisons between check and other treatments—0.41 lbs
Comparions between treatments except check— 0.53 lbs

TESTS WITH CHLORINATED COMPOUNDS.—This series of experiments was set out in the fall of 1940. Compounds used were as follows:

D-D mixture (1.3 dichloropropene[1] and 1.2 dichloropropane).
Chloropicrin
Allyl alcohol
Allyl chloride
Methallyl alcohol
Methallyl chloride

[1] Originally called dichloropropylene. The present usage appears to be more in line with current terminology.

The plots were located in three areas well enough separated with regard to rainfall and altitude to test the effectiveness of the fumigants under varying weather and soil conditions. All the materials used were injected at the rate of 150 pounds per acre, the injection being made after the mulch paper had been laid and at the points where the plants were to be planted, approximately 12 feet apart. Actually therefore, the materials were applied only to the strips of soil covered by the paper or approximately three-fifths of the actual area included in the plot.

The early response to the treatments was extremely slight. In one of the three areas on April 1, 1941, 6 months after planting, a slight response to all the treatments was noted with special reference to the methallyl compounds and allyl alcohol. In another area, allyl alcohol was the only treatment noted as showing any response apart from the chloropicrin plots which exhibited the typically darker green color of plants grown in chloropicrin treated soil.

On the basis of the visual evidence for response by mid-summer, plans were drawn for detailed testing of allyl alcohol in the fall of 1941 for at that time there was no evidence calling attention to D-D mixture as a potentially effective fumigant. In the late fall of 1941, however, and positively by February of 1942 as the plants were in or approaching the flowering stage, the response in the D-D plots became increasingly evident so that by plant crop harvest time it was clear that D-D mixture and chloropicrin were the only compounds in the tests which were of any importance. This was particularly true in the driest of the three areas, an area which is badly infested with *Anomala orientalis* (Waterh.), along with *Heterodera* and *Pythium* species. Plant crop yields, however, taken soon after the differences in plant growth developed noticeably, showed no significant differences, although by that time the difference in appearance of the plants was well marked. The data are in table 6.

With the development of the ratoon growth the superiority of D-D mixture and chloropicrin became increasingly evident and by ratoon harvest time in the summer of 1943 had become most pronounced. Again, there were great differences between the three areas. In Area 1,

Table 6.—Comparison of chlorinated compounds including D-D mixture and chloropicrin when used at the rate of 150 lb./A. Summary of plant crop and first ratoon fruit harvest data.

Treatment	Mean Fruit Weight in Lbs							
	Area 1		Area 2		Area 3		All 3 Areas	
	Plant Crop	First Ratoon	Plant Crop	First Ratoon	Plant Crop	First Ratoon	Plant Crop	First Ratoon
Allyl alcohol	4.68	2.07	5.71	3.62	5.08	3.41	5.16	3.03
Allyl chloride	4.40	2.06	5.64	3.50	5.03	3.13	5.02	2.90
Check	4.52	2.06	5.62	3.58	4.96	3.07	5.03	2.90
Chloropicrin	4.39	2.55	5.72	3.55	5.07	3.36	5.06	3.15
D-D mixture	4.61	2.66	5.80	3.76	4.96	3.55	5.12	3.32
Methallyl alcohol	4.31	2.06	5.46	3.55	4.89	3.04	4.89	2.88
Methallyl chloride	4.43	1.87	5.70	3.56	4.88	3.14	5.00	2.86

the dry area previously referred to, the D-D and chloropicrin treatments made the difference between failure and a crop; in Areas 2 and 3, gains were much less pronounced but nevertheless important. Tables 6 and 7 give the data for average

Table 7.—Comparisons of the combined mean first ratoon fruit weights for the different treatments listed in Table 6.

Treatment		Mean Fruit Wt. (lb)	Diff. from Prev. Value*
Material	Dosage lb/A		
D-D mixture	150	3.321	
Chloropicrin	150	3.148	0.173
Allyl alcohol	150	3.031	0.117
Check		2.905	0.126
Allyl chloride	150	2.895	0.010
Methallyl alcohol	150	2.882	0.013
Methallyl chloride	150	2.853	0.029

* Critical difference necessary for significance at odds of 19 to 1—0.173.

weight of fruit harvested but this is difficult to interpret in terms of actual yield per acre in ratoon unless the factor of holdover is taken care of by suitable field practices. The problem of first ratoon suckers "holding over" and not fruiting until the following year is an old one in pineapple fields and is rendered more acute when the growth of the plants is more strongly vegetative.

In both Areas 2 and 3, particularly in Block 2 of Area 3, holdover was very much increased as a result of treatments with D-D and chloropicrin. Area 1 had been treated to induce flowering at the normal time (Kerns 1936) (Wendt 1936) and the difference in the number of fruits as shown in table 8 is a real measure of the difference between the treatments and the checks. The differences in the number of fruits in these plots are not due to holdover but to the failure of the plants in most of those plots to produce suckers capable of fruiting. The difference in appearance between the D-D and untreated plots is shown in figure 1. Expressed in terms of tons per acre yields, the ratoon crop from this area amounted to 18.16 for the D-D mixture plots, 16.76 for the chloropicrin and 3.01 for the check untreated plots.

D-D Mixture as a Soil Fumigant.—Since the summer of 1942 when the response to fumigation with D-D mixture was first evidenced beyond doubt, it has

Table 8.—Actual first ratoon fruit yields from Area 1 expressed in terms of tons per acre.

Treatment	No. of Plots[1]	Total Fruits Harvested	Total Fruit Weight		Yield in Tons/A
			lbs.	tons	
D-D mixture	2	850	2251	1.1255	18.16
Chloropicrin	2	809	2077	1.0385	16.76
Allyl chloride	2	246	497	0.2485	4.06
Check	4	354	747	0.3755	3.01
Methallyl chloride	2	201	371	0.1855	2.99
Allyl alcohol	2	131	271	0.1355	2.19
Methallyl alcohol	2	81	167	0.0835	1.35

[1] One plot area equivalent to 0.03099 of an acre.

been apparent that this new material offered possibilities not only for pineapple soils but for agriculture in general. Chloropicrin, in view of its cost, its extremely unpleasant lachrymal effects and the repeatedly stated necessity for ground cover to render it efficient, was, and is precluded from general use (Godfrey & Young 1943).

On the other hand, D-D mixture, while capable of causing irritation to the skin of sensitive persons, is easy to handle and, most important, will give response when applied without soil cover.

FIG. 1.—Response to soil fumigation with D-D mixture. Plants in foreground typical of those growing in untreated soil in the area. Plants in background growing in soil treated with D-D mixture at the rate of 150 lb per acre. Photographed in fall of 1942, two years after treatment.

Preliminary results in soils devoted to vegetable growing were mentioned in the introductory announcement (Carter 1943). In this case, root-knot nematodes were a serious factor and although no paper cover was used in one series of plots, the results clearly indicated a high nemacidal value. The harvest results[1] are in table 9. Figure 2 illustrates the difference in development of root-knot of tomato plants between the check and treated plots. No further studies with nematode soil were made except one in which the writer's interest was limited to the method of application, in this case in irrigation water. D-D was first emulsified with diesel oil, as described in a recent note (Carter 1944). The emulsion was then introduced into the irrigation water.

The amount for each furrow was calculated at the rate of 200 lb. of D-D per acre and introduced into the irrigation stream at the head of each furrow. When the stream reached the end of the furrows, small dams were raised to hold the water. This involved a gradually increasing quantity of emulsion in the furrow from the intake to the end, and it was clear that the steepness of the furrow would be an important factor in getting an even distribution of fumigant. Favorable yield results from this experiment, however, have been reported by the Director of the Hawaiian Agricultural Experiment Station (1944).

For the average grower, however, application with the disc plow just prior to planting the bed would probably be the most practical method of fumigation.

[1] Taken with Collin B. Lennox, formerly of the Hawaiian Sugar Planters' Association, to whom the writer is much indebted for cooperation.

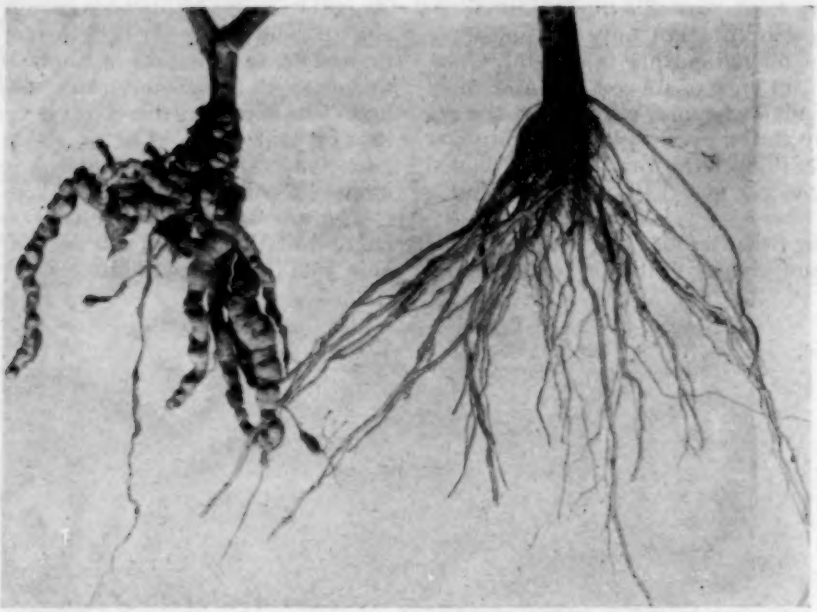

FIG. 2.—Roots from tomato plants. The one on the right was grown in soil treated with crude D-D mixture at the rate of 200 lbs per acre without soil cover; the one on the left was from an untreated plot.

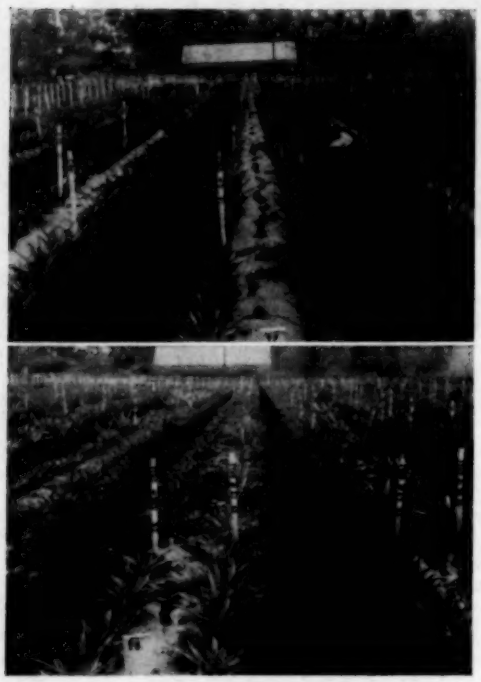

FIG. 3.—Difference in weed growth following treatment with D-D mixture at the rate of 200 lbs per acre ploughed in prior to planting. Above: Treated. Below: Check.

One experiment has progressed now to the point of indicating that this method can be developed as a practical solution to the application problem. By means of a simple device consisting of a small pump geared to the plow wheel, a thin stream of D-D mixture was dropped at the bottom of the furrow ahead of the plow disc. The plow cut was approximately 12″ wide and the application was made on the last plowing in very dry and friable soil. The first response to this application was unexpected and showed as a material reduction in weed growth in the treated areas. Figure 3 shows the difference in weed growth, particularly *Richardia scabra*, in the treated and check areas. Plant growth response up to six months after treatment is shown in figure 4 and compares favorably with that obtained with similar dosages of the same material applied with a hand injector.

D-D AS AN INSECTICIDE.—Although the action of a soil fumigant is on the whole complex of organisms in the soil and plant growth response is the real criterion by which the usefulness of a soil fumigant can be judged, data on the action on specific organisms can serve a useful purpose. Furthermore, the potential

Table 9.—Harvest records from vegetable plots treated with D-D mixture. Treated Sept. 18. Planted Sept. 21, 24 and 29, 1942. Harvest records made Nov. 16, 20 and Dec. 10, 1942.

Section	Soil Treated Through Paper: No. of plants	No. showing nematode injury	Size and vigor	Check: No. of plants	No. showing nematode injury	Size and vigor	Soil Treated Without Paper: No. of plants	No. showing nematode injury	Size and vigor	Check: No. of plants	No. showing nematode injury	Size and vigor
						November 16, 1942						
Chinese Cabbage (Wong Bok)[1]												
A	4	0	fair	9	4	good	9	0	excel.	6	4	fair
B	6	1	excel.	7	5	fair	8	0	excel.	6	6	good
C	5	0	good	6	0	good	8	0	good	7	7	poor
Beets (Detroit Dark Red)[2]												
A	24	0	excel.	11	8	poor	19	0	good	6	6	very poor
B	32	0	good	7	7	very poor	40	6	excel.	22	22	very poor
C	27	2	good	27	27	fair	34	1	good	37	37	very poor
						November 20, 1942						
Bush beans (Bountiful)[3]												
A	17	3	good	15	15	fair	19	1	good	17	17	very poor
B	18	0	good	15	15	fair	14	0	good	14	14	very poor
C	13	0	good	16	12	poor	15	0	fair	17	16	poor
Carrots (Chantenay)												
A	32	2	good	18	18	fair	30	4	good	32	32	very poor
B	25	4	good	20	18	fair	28	3	good	15	15	very poor
C	50	15	excel.	38	27	good	37	15	good	36	36	poor
						December 10, 1942						
Cowpeas (Calapproved)[4]												
B	17	2	good	15	15	fair	16	0	good	14	14	poor
Tomato (Bounty)[5]												
B	2	0	good	2	2	very poor	2	1	fair	2	2	very poor
C	3	1	good	3	3	fair	3	0	fair	3	3	very poor

[1] The Chinese cabbage is not severely attacked by nematodes. The plants showing a large population of galls on the roots were usually small ones. However, there were a few large plants which carried many galls.

[2] The beets are very severely attacked by nematodes. The untreated plots produced no marketable beets while the treated plots were in good condition. A few plants in the latter were showing a late nematode infestation.

[3] The bush beans did not show a marked difference at the time the green beans were ready for picking (50 days). At the time of pulling for nematode examination a marked difference was noted in aerial growth.

[4] The cowpeas showed a noticeable gain in production of pods on the treated plots. Better development of nitrogen nodules noticed in treated plots.

[5] The tomatoes on the untreated plots showed a high proportion of blossom-drop with a very poor to no fruit set. A fair to good fruit set was obtained on the treated plots.

usefulness of a material as new as D-D mixture as an insecticide *per se* is worth investigation. Data already published (Carter 1944) (Stone 1944) indicate that D-D mixture is effective against soil inhabiting larvae. The fumigant has also shown high toxicity against the rice weevil, *Sitophilus oryza* (Linn.), which has been used as the experimental animal in many comparative tests. Considerable value against other pests of stored grain and household insects is indicated by experiments with termites (Schmidt) and *Lyctes* beetles in furniture. In both the latter cases, the D-D was applied to the wood by means of a medicine dropper with a point drawn out to almost capillary size. In both cases, this simple treatment was effective and in neither case has there been any recurrence of the infestation.[1]

TOXICITY OF THE FRACTIONS OF D-D MIXTURE.—Since D-D is a mixture of two compounds and their isomers, the toxicity of the various fractions is of considerable interest. It was known, for example, that propylene dichloride (1.2 dichloropropane), one of the compounds of the mixture, has a low toxicity; that of the 1.3 dichloropropene was unknown. Fractions of D-D mixture were separated on the basis of boiling point and the toxicity of these fractions was determined using the rice weevil as an experimental animal. Forty weevils were used for each separate test and these were distributed in four lots of 10 each, suspended in cloth bags in a fumigation chamber. The data are listed in table 10 and figure 5 together with the results following fumigation with a C.P. grade of propylene dichloride and a mixture containing 99 per cent propylene dichloride and 1 per cent of the high boiling point fraction. Results with chloropicrin are appended to the table for comparison. It is seen that the higher boiling points are the more toxic, with the 103°–105° C. fraction at least the equal of the 112° C. fraction, but the lowest boiling point, 97° C., which theoretically should have been propylene dichloride, is much more toxic than the C.P. material. This

[1] Limitations imposed by reaction of the fumigant with the material fumigated have not been studied but this information would be necessary before practical use of these findings could be made.

indicated a contamination of the lower boiling point fraction which had had a pronounced synergistic effect. The tests made with the mixture compounded of 99 per cent C.P. propylene dichloride and 1 per cent of the high boiling point fraction confirmed this, for the addition of the 1 per cent high boiling point fraction, of no consequence of itself at that extreme dilution, nevertheless increased the toxicity of the C.P. propylene dichloride at the 50 per cent mortality level four times and at the 72 per cent level twice.

The toxicity of the mixture, while slightly less than that of the higher boiling points, is none the less so close as to indicate that the less toxic fractions are important synergistically.

A basis for the development of new and perhaps cheaper and more effective soil fumigants would seem therefore to be the utilization of the toxicity of 1.3 dichloropropene and its isomers along with other chlorinated compounds which would serve not only to dilute the more toxic and unstable compound for more effective distribution in the soil but would also result in an increased toxicity due to interactions between the two compounds.

DISCUSSION.—From the results of these experiments we can see that with a crop as slow in maturing as is pineapple, the effects of soil fumigation may not be manifested for months and the economic returns not accrue until the second or ratoon crop is harvested, approximately three years after planting. It is obvious that this delayed response is not due to a carry-over effect of the fumigant *per se* nor to the depression of pathogenic species for so long a time. In Area 1, table 8, where growth response showed clearly by plant crop harvest time, *Anomala* larvae and the galls of the root-knot nematode could easily be found in both the chloropicrin and D-D plots. The significant difference between these two plots and others in the same experiments was in the vastly improved root systems on the plants in the chloropicrin and D-D plots. The most logical explanation for the difference in plant growth would seem to be that the relative freedom from pathogens brought about by the fumigation permitted the

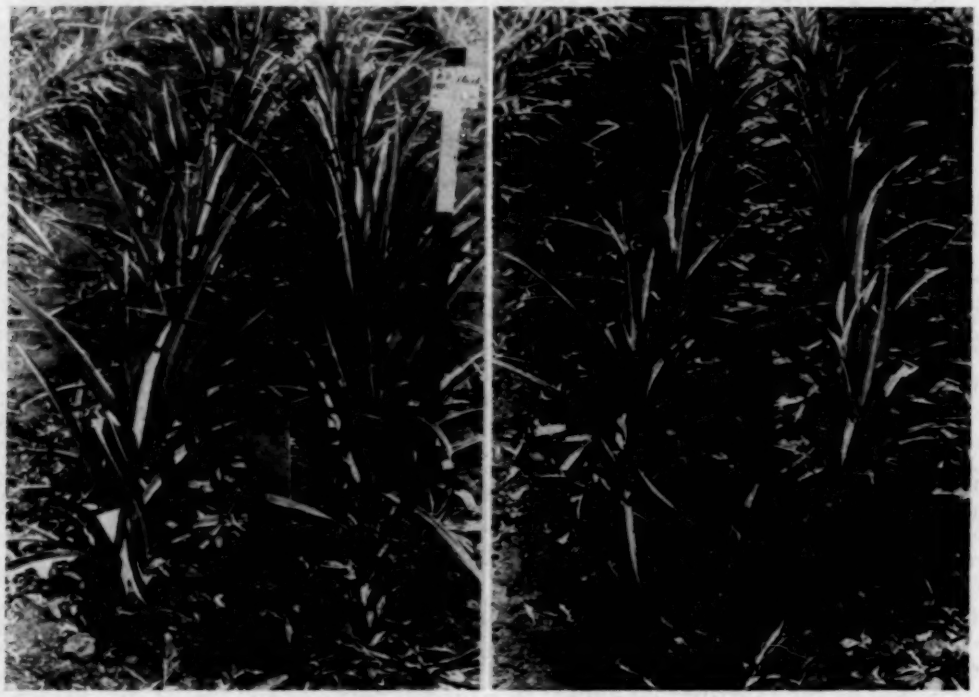

FIG. 4.—Response 6 months after treatment with 200 lbs of D-D mixture per acre ploughed in prior to planting. Left: Treated. Right: Check.

plant to develop a huge root system in the early period of its growth. This root development was adequate, not only to build up a large plant which assured the development of a strong ratoon sucker, but also to function in spite of the accrued pathogenic complex.

The end results as expressed in plant crop and ratoon yields indicate that the early response in the chloropicrin plots due to the effects of the fumigant on the nitrifying bacteria in the soil (Tam & Clark 1943) had no measurable effect on yield.

With short term crops, planted in soil which had nematodes as the obvious soil pathogen, the effect of the fumigation was to very greatly reduce nematode injury, but the response as a whole cannot be directly ascribed only to the elimination of nematodes.

In view of the difficulty of assessing the effect of single species in the soil complex and the insuperable difficulties inherent in any attempt to evaluate the interactions of all the species together it would seem that plant response measured in terms of yield is the best index of the value of a soil fumigant and that this response is directly associated with the development of a superior root system.

As a corollary to this, it can be expected that in soils which respond to fumigation, fertilizer requirements might well change in view of the better opportunity for the absorption of nutrients by plants with adequate root systems.

Whether or not soil fumigation brings about a reduction in susceptibility of pineapple plants to mealybug wilt remains to be seen but as far as young plants are concerned, the evidence is negative. For chloropicrin the data have been presented in detail (Carter, in press); for D-D mixture, recent experiments have shown conclusively that treatment of the soil with D-D mixture affords no protection to young plants. For older plants and particularly for first ratoons, experiments are in progress with no conclusion possible for some time.

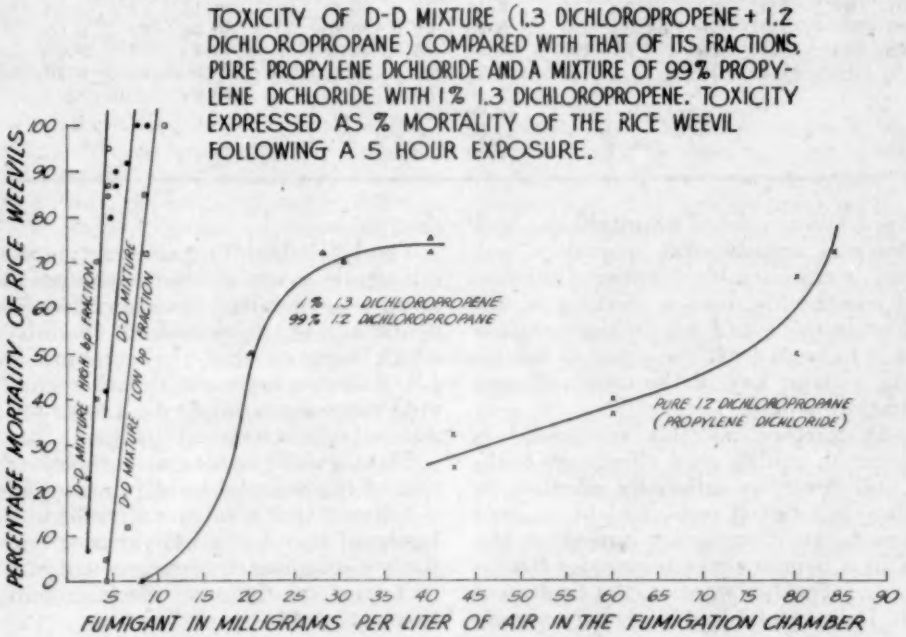
TOXICITY OF D-D MIXTURE (1.3 DICHLOROPROPENE + 1.2 DICHLOROPROPANE) COMPARED WITH THAT OF ITS FRACTIONS, PURE PROPYLENE DICHLORIDE AND A MIXTURE OF 99% PROPYLENE DICHLORIDE WITH 1% 1.3 DICHLOROPROPENE. TOXICITY EXPRESSED AS % MORTALITY OF THE RICE WEEVIL FOLLOWING A 5 HOUR EXPOSURE.
PERCENTAGE MORTALITY OF RICE WEEVILS
0
10
20
30
40
50
60
70
80
90
100
D-D MIXTURE HIGH bp FRACTION
D-D MIXTURE
D-D MIXTURE LOW bp FRACTION
1% 1.3 DICHLOROPROPENE 99% 1.2 DICHLOROPROPANE
PURE 1.2 DICHLOROPROPANE (PROPYLENE DICHLORIDE)
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
FUMIGANT IN MILLIGRAMS PER LITER OF AIR IN THE FUMIGATION CHAMBER

FIG. 5.—Toxicity of D-D and other compounds, employed as fumigants to kill the rice weevil.

SUMMARY.—The study of soil fumigation was begun as a result of evidence that as pineapple soils became older, the pathological complex increased in severity and it was clear that some contrary action was necessary if production was to be maintained. A second reason was the observation that first ratoons grown on virgin land and in some cases on land treated with chloropicrin were less susceptible to mealybug wilt than were ratoons on old land.

Table 10.—Toxicity of the fractions of D-D mixture compared with that of D-D mixture, propylene dichloride and chloropicrin, toxicity being expressed as percentage mortality of the rice weevil.

D-D Mixture		D-D bp 112° C.		D-D bp 103–5° C.		D-D bp 97° C.		Propylene Dichloride		D-D bp 112° C. 1%—Propylene Dichloride 99%		Chloropicrin	
Mg/L	Mortality	Mg/L	Mortality	Mg/L	Mortality	Mg/L	Mortality	Mg/L	Mortality	Mg/L	Mortality	Mg/L	Mortality
4.34	42												
4.79	80	2.25	7	2.25	5	4.29	0	42.9	25	8.04	0	0.61	5
5.23	87	2.25	15	2.25	22	4.29	0	42.9	32	16.08	15	1.57	75
5.23	90	2.25	23	3.37	47	4.29	5	60.0	37	20.10	50	1.57	82
6.51	92	3.37	40	4.05	75	6.43	12	60.0	40	28.14	72	3.05	95
7.59	100	3.37	70	4.50	100	8.58	72	80.0	50	30.50	70	3.05	98
8.68	100	4.50	85	4.50	100	8.58	85	80.0	67	40.0	72	3.05	98
		4.50	87			10.72	100	84.0	72	40.0	75	6.10	100
			95			21.40	100			40.0			
						42.90	100						
						60.00	100						
						77.00	100						

Weed killers proved unsuitable as well as various organic soil amenders but among a considerable number of chlorinated compounds, one, a mixture of 1.3 dichloropropene and 1.2 dichloropropane proved to be at least the equal of chloropicrin without any of the disadvantages of that compound.

D-D mixture, as this compound is designated, can be used effectively without soil cover, is expecially effective in nematode infested soils, and in an area where *Anomala* larvae are important factors in a complex which includes *Heterodera* and *Pythium* species, the treatment with D-D resulted in especially significant gains.

The 1.3 dichloropropene fraction of the mixture is evidently the most toxic but there is synergism between that compound and other fractions of the mixture which suggests that the combination of 1.3 dichloropropene with other chlorinated compounds might be a basis for additional research on soil fumigants.

Plant growth is seen as the best criterion of the value of a soil fumigant and it is believed that whatever the effect of the fumigant may be on individual species of the soil complex, the development of good root systems follows effective fumigation.—12-5-44.

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Effect of *Lygus* spp. on Seed Production and Growth of Guayule in California

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Guayule, *Parthenium argentatum* Gray, is a rubber-producing plant found growing in the wild state to a limited extent in semiarid regions along the Rio Grande in Texas, and more extensively in similar habitats in Mexico. The branches and roots contain most of the rubber, very little being found in the leaves and fruiting parts. The plant is propagated from seed in nurseries for one growing season, then transplanted into fields. Profitable production can apparently be obtained after guayule grows in the field for from 3 to 5 years, depending upon growth and rubber content in the various localities. A variety known as "593" was mainly used for war emergency plantings in California, where over 30,000 acres were growing, mostly under irrigation by March 1944.

It is characteristic of guayule to flower and produce seed continuously from early spring to late fall when favorable moisture is constantly maintained. Under irrigation the flowering occurs more profusely after each irrigation. When in the flowering and seeding stage, guayule is a very favorable breeding host for several plant bugs. By far the predominant species in California during 1943 was *Lygus hesperus* Knight, which constituted 92 per cent of the 2880 *Lygus* adults collected from guayule in the Salinas and Bakersfield districts. Other species associated with *L. hesperus* on guayule included *L. apicalis* Fieber, *L. sallei* Stål, and *L. elisus* Van Duzee, in the Salinas district, and *L. elisus* in the districts north of Bakersfield.

In recent years *Lygus hesperus*, as well as other closely related species, has been found to damage the seed of various crops. Shull, *et al.* (1934) showed that *L. hesperus* reduced plant growth, caused flower fall, and reduced the seed yield by shriveling some seeds of caged alfalfa plants. Sorenson (1936) showed that the feeding of plant bugs caused an increase in the percentage of shriveled alfalfa seed in Utah. Stitt (1940) showed that *Lygus* increased flower-fall and shriveled seed in the alfalfa seed fields of southern Arizona and California. Hills (1941) showed that plant bugs reduced the weight and viability of sugar beet seed.

The presence of *Lygus hesperus* in abundance on guayule naturally led to the suspicion that it caused similar damage to its seed. To determine this point it was necessary to study the effect of the insect on the seed and plant under caged conditions.

Insectary Experiment with *Lygus hesperus*.—Thirty small guayule seedlings having from 2 to 3 flower stalks with blooms just starting were taken up from a nursery with as little disturbance of soil around the roots as possible and set in 8-inch pots August 26, 1943. Two days later 20 of these plants, which were in about equally good condition, were covered with small cages and placed in a screened insectary. One, third-instar, *Lygus hesperus* nymph was put in each of 10 cages and the other 10 caged plants were used as checks arranged as a randomized block. From September 4 to 27 the cages were examined at intervals of 2 or 3 days, during which time any nymphs found dead or transformed were replaced with other nymphs, and all other insects were removed from the plants. Each time an examination was made, the *Lygus* nymphs were found on the underside of the flower clusters where the seed was most accessible.

By September 27 the seed was fairly mature, and all nymphs were removed. The cages were taken off the plants, and the seed clusters in each cage were enclosed in small white bags to prevent loss from shattering. After the seed ripened it was collected from each plant, cleaned by hand, weighed, counted, and germinated.[1] The results of this experiment are given in table 1.

There was a highly significant difference between the two treatments, in the weight and viability of the seed showing that the

[1] Germinations and filled-seed counts were made by Dr. H. M. Benedict and staff of the Bureau of Plant Industry, Soils, and Agricultural Engineering. The seeds were subjected to a special treatment which was found to break whatever dormancy might be present, which made them as easy to germinate as most other seeds.

presence of the insect greatly reduced the number of good seeds produced by the plants. The filled-seed count was obtained by cutting open the seeds left on the blotters after the specified germination period and the number of filled seed so counted was combined with the number that germinated as an index of seed quality. Three of the 10 infested cages contained no filled seed at all, which indicates that the bugs could have done greater damage if more seeds had been available. On the basis of this experiment, however, each nyymph destroyed more than an average of 1 seed per day.

Table 1.—Effect of one *Lygus hesperus* nymph per plant on the weight and viability of guayule seed (10 replicates).

Treatment	Total Number of Seeds	Weight 100 Seeds in Grams	Per Cent Germination After 12 Days	Per Cent Filled Seed
Checks	1015	0.124	28.7	31.7
Infested	1091	0.089	2.2	2.7
Difference required at 5% level		0.013	6.6	6.4

FIELD-CAGE EXPERIMENTS WITH *Lygus hesperus*.—Two types of field cages, one using cheesecloth and the other wire screen, were used to determine the feeding effects of *Lygus hesperus* on seed production and growth of guayule plants growing the second season under field conditions. Results from the experiments with the two types of cages corroborate results from the insectary cages in regard to weight and viability of the seed, except that the contrast in seed quality between the infested and uninfested plants is less marked because seed which ripened from May 8 to Sept. 13 was compared, and *Lygus* did not affect them throughout the entire period. In addition, they show that growth and seed production were reduced by the insect, which apparently was forced to feed on the current season's shoots owing to lack of seed in the desirable food stage.

On May 8, five females and two males of *Lygus hesperus* were placed in each of five cheesecloth cages, and five cages were arranged as checks in a randomized block. The cages were similar to those described by Hills (1941), except that they were much smaller, being only 11 inches in diameter and 18 inches tall. All mature seed was removed, and all insects were removed from the plants by hand and by spraying before the plants were caged but *Lygus* females had already laid eggs in the plants, and much seed was past the susceptible stage for damage by the insect.

At intervals the cages were inspected and, as nearly as possible, all insects were removed from the checks, and all except *Lygus hesperus* were removed from the infested cages. In all, 15 *Lygus* nymphs were removed from 4 of the 5 cheesecloth check cages on May 26, June 7, 12, and 19, and July 22, which shows that these cages had not been kept entirely insect free, but the numbers were kept low enough to show a contrast with those in the infested cages. Forty-eight nymphs were removed from the fifth check cage on the above dates, and because of this high infestation this check and its corresponding infested cage were discarded. The mature seed was collected from the 8 remaining cages July 22, and all insects were removed. Seed that matured after July 22 was collected from the plants September 13. To avoid any loss, all the seed was cleaned by hand instead of by mechanical means.

By July 22 there was considerable difference in the size of the plants in the infested and check cages and the contrast persisted until after September 13 (Fig. 1), at which time plants in the infested cages were all much smaller and bore fewer flowers than those in the check cages. When a population of *Lygus* nymphs does not have seed in the predough stage on which to feed, the nymphs apparently go down to feed on the current season's stems, and such feeding inhibits growth and prevents further flowering. On July 22 there was an average of 5.6 dead nymphs per cage in the infested cheesecloth cages, indicating that they had not had sufficient seed for food and were forced to feed on the stem tissues, which caused a 27 per cent mortality among them.

An experiment was conducted in May and June 1944 to verify the feeding effect of *Lygus hesperus* on guayule, and the nymphal mortality in the absence of seed. On May 18, silk-covered cages were placed over 4 small guayule plants which were very similar in appearance and 20 third-instar *L. hesperus* nymphs were placed in 2 of the 4 cages while 2 were left insect-free as checks (Fig. 1, Below). At 4-day

intervals nymphal mortality was determined, and at each time 20 live nymphs were reinstated in each of the two cages. Nymphal mortality averaged 77.5, 57.5, and 77.5 per cent, respectively, on May 22, 26, and 30. All *Lygus* were removed from the infested plants May 30.

On June 8 the two treatments were photographed and the 2 pairs were so similar that it was difficult to distinguish between them. Growth on the infested plants was practically stopped whereas normal growth continued in the checks, and by July 15 the infested plants were just beginning to show signs of producing normal growth.

With large populations of *Lygus* nymphs it is quite probable that injury to plant growth might occur under field conditions if the seed supply was depleted but only slight damage to growing shoots was encountered in a field during the 1943 season.

Results of examinations of the seed collected July 22 and September 13 from the cheesecloth cages are given in table 2.

There was a significant increase in the average weight and viability of seed collected from the check cages July 22 over that taken from the infested cages. Very little seed, and that of poor quality, was collected from the infested cages September 13 compared with the amount and quality of seed collected from the check cages. This condition was apparently caused by the feeding of the insect on the growing shoots. Only 700 seeds were obtained from the 4 infested cheesecloth cages on September 13 and most of these had shattered prior to July 22 and were taken from the folds of the cotton pads wrapped around the base of each plant.

With the other type of cage in use, 10 screen cages measuring 3 feet square and 4 feet high, arranged as a randomized block, were used with two guayule plants in each. Ten females and three males of *Lygus hesperus* were introduced into each of five cages May 8, 1943, after the plants

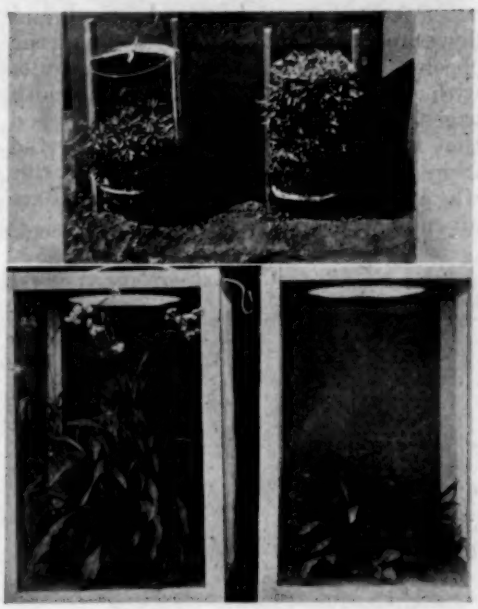

FIG. 1.—Growth and flowering of guayule inhibited by feeding of *Lygus hesperus* on the growing shoots: Above, The plant on the left is typical of the size of plants in the infested cheesecloth cages, compared with the plant on the right kept nearly free of *Lygus* bugs; Below, the plant on the right shows inhibited growth caused by 20 *L. hesperus* nymphs 21 days after the initial infestation, compared with the *Lygus*-free plant on the left.

in all the cages had been sprayed and all ripe seed had been removed from them. Inspections were made in the check cages May 27, June 7, 12, and 19, and July 22,

Table 2.—Effect of *Lygus hesperus* on guayule as indicated by the plants in 8 cheesecloth cages (4 replicates), 1943.

Treatment	Seed Collected July 22 (800 seeds per sample)			Seed Collected Sept. 13 (400 seeds per sample from checks and all seed from infested cages)	
	Weight of Seed per Plant	Germination After 12 Days	Filled Seed	Weight of Seed per Plant	Filled Seed
Checks	9.9 gms.	33.4%	33.8%	4.8 gms.	44.9%
Infested	7.2	20.5	21.2	0.2	14.6
Difference required at 5% level	2.3	12.2	12.4	1.04	8.9

during which time 94 *Lygus* adults and nymphs were removed—which shows that these screen cages were not so insect-proof as the cheesecloth cages. The mature seed was collected from all of the 10 screen cages July 22, at which time all insects were removed. The plants in the infested cages showed greatly reduced growth and flowering compared with those in the checks. This was similar to the results with plants confined in the cheesecloth cages. As with the cheesecloth cages, seed that matured after July 22 was collected from the cages September 13, and this was also cleaned by hand. The results are given in table 3.

Table 3.—Effect of *Lygus hesperus* on guayule seed as indicated by results in 10 screen cages (5 replicates), 1943.

Treatment	Seed Collected July 22 (800 seeds per sample)			Seed Collected Sept. 13 (400 seeds per sample)		
	Weight of Seed per Cage	Germination After 9 Days	Filled Seed	Weight of Seed per Cage	Germination After 9 Days	Filled Seed
Checks	10.12 gms.	38.1%	42.1%	9.66 gms.	21.2%	27.5%
Infested	10.68	27.5	31.0	0.85	6.3	9.1
Difference required at 5% level		8.2	10.3	1.01	7.6	9.4

There was little difference in the weight of seed taken from the two treatments on July 22, but there was a significant difference in the quality as expressed by germination and total filled seed. Much more seed was collected from the check cages on September 13 than was collected from the infested screen cages, and there was again a highly significant difference in quality in favor of the check cages. A direct comparison of seed quality between the seed collected from the screen and cheesecloth cages cannot be made since over half the seed in the screen cages had shattered by July 22 and could not be recovered from the ground, while practically all the seed was recovered from the plants confined within the cheesecloth cages.

Type of Damage to Guayule Seed.—Dissection of guayule seed from the *Lygus*-infested cages showed three types of seed with gradations between them. There were normal mature embryos, collapsed embryos, and immature embryos. The collapsed embryos represent those fed on by *Lygus* in the predough stage. The proportion of embryos that normally fail to develop in guayule variety No. 593 apparently ranges from 40 to 70 per cent, and this accounts for the low percentages of germination even under comparatively insect-free conditions.

Lygus Populations in the Field, and Their Influence on Guayule Seed.—Quantitative samples taken with a sampling cage described by Hills (1933) and the sweep net showed that *Lygus* populations on guayule constituted 64 per cent of the total number of insects on the plants in the Salinas and Bakersfield districts during 1943, with the exception of thrips and a few aphids. Sampling-cage counts made on guayule within six check plots of an experiment at Salinas May 21, June 4, and June 14 showed an average per plant of 9.1 *L. hesperus* adults and nymphs of the first generation, and seed from these plots showed an average germination of 28.9 per cent. A similar experiment sampled August 6, August 23, and September 8 showed an average per plant of 13.8 second-generation adults and nymphs and an average of 13.3 per cent of seed from these plots germinated.

Forty samples, each collected by both the sampling-cage and sweep-net methods in the same area served as a basis for converting sweep counts to number per plant. Sweeps were made by striking 2 guayule plants with each net stroke. If the number taken per 5 sweeps is divided by 3, a fairly good estimate of the actual number per plant is obtained. A survey made September 15, 1943, in irrigated guayule fields from Salinas to San Ardo, showed an average of 38.1 *Lygus* per 5 sweeps. On September 19 there was an average of 70.8 *Lygus* per 5 sweeps in irrigated guayule fields between Bakersfield

and Tracy. On September 29, fields near Wasco showed an average of 220 *Lygus* per 5 sweeps. The populations given above do not include *L. sallei*, which occurs only in the California coastal areas. The effects of feeding of this insect are quite different from those of the other plant bugs found on guayule. It damages the growing terminals and apparently does not feed on seed as do most other plant bugs.

Most guayule seed collected from California fields during the 1943 season contained from 10 to 30 per cent filled seed. Weather conditions and soil fertility, no doubt, influence guayule seed production, as was indicated by Whitehead & Mitchell (1943), but, on the basis of cage studies, from 40 to 60 per cent of the seed produced under the climatic conditions prevailing at Salinas might well germinate if kept free from *Lygus*.

FEEDING EFFECTS OF *Lygus sallei*.—The damage to guayule caused by the feeding of *Lygus sallei* is quite different from that caused by most other plant bugs in that the growing tips are fed upon, their growth being thereby checked. Along the coastal areas of California in April, May, and June individual plants or sizable patches in field plantings may fail to bloom and appear diseased. This condition (Fig. 4) is attributed to the injurious feeding effects of *L. sallei*. The plants are apparently not diseased, since they recover and show normal growth several months after the insects have been removed from them. The numbers of *L. sallei* were observed in a field near Salinas during the spring and summer of 1943, and the largest numbers were found at the peak of the first generation in May. On May 22 there were, on an average, 7.6 adults and nymphs per plant in 5 check plots, compared with 5.9 adults and nymphs per plant on June 22, or at about the peak in numbers of the second generation. Third-generation numbers of this insect were very low, and this condition persisted during the remainder of the season.

Two *Lygus sallei* nymphs were placed on each of ten 4-leaf guayule seedlings, left for 5 days, and then removed. Feeding of the insect caused the terminal growths to die, 8 of the 10 plants yellowed as though they were diseased, and 2 were killed. After 53 days there was considerable difference in the size of the plants which had been fed upon by the insect, as compared with the check plants (Fig. 5), although the small plants began to show normal growth about 3 months after the nymphs were removed from them.

SUMMARY.—Under irrigated conditions in California, guayule remains in flower from early spring to late fall. This plant has been found to be a very favorable breeding host for several plant bugs, the most important of which are *Lygus hesperus* Knight and *L. sallei* Stål. *L. hesperus* occurs throughout the extensive guayule plantings in central and northern California, whereas *L. sallei* occurs only along the coastal areas.

FIG. 2.—Damage to plantation guayule caused by the feeding of *Lygus sallei* on the growing tips which were stunted and in which flowering was inhibited (left) compared with the appearance of a normal plant (right).

Under cage conditions *Lygus hesperus* was found to reduce the weight and viability of guayule seed. The quality of seed produced under field conditions was also lowered by the insect. It was demonstrated under caged conditions that as long as seeds of pre-dough stage were available the insect sucked the contents from them, but when these were lacking they fed on the current season's shoots with the result that subsequent growth and flowering were inhibited.

Lygus sallei feeds primarily on the terminal growth of guayule, causing plants on which it feeds to appear yellowed and stunted as though diseased. When the insects were removed from damaged plants, the plants resumed normal growth after several months, indicating that no disease was present, but that feeding of the insect was injurious to them.—11-8-44.

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The Role of Arsenicals in Reducing Lygus Injury to Guayule Seed

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Arsenicals and arsenical-sulfur mixtures have been used successfully in the control of hemipterous insects on cotton in the southwestern part of the United States since 1933, as was reported by Cassidy & Barber (1939). The results obtained in Arizona were corroborated on cotton in New Mexico by Eyer & Medler (1942). The percentage reductions in hemipterous insect populations obtained by use of the arsenical-sulfur mixtures were not large, and they did not appear to be entirely responsible for the differences in yield of cotton between the treated and check plots; therefore, it was felt that arsenicals in the sulfur-arsenical mixtures were beneficial in some way which could not be explained on the basis of reduced insect numbers.

Experiments were conducted near Salinas, Calif., during the 1943 season to determine the effect of sulfur, calcium arsenate, cryolite, and sulfur-arsenical mixtures on the Lygus populations found reproducing on guayule. Two similar latin-square experiments (six replicates) were conducted. The plots were 42 feet square, and the dusts were applied with rotary hand dusters. Six applications were made in the Mary Hansen field at approximately weekly intervals between May 8 and June 14, 1943, and six applications in the Wallace tract at approximately weekly between July 26 and August 31, 1943 (Table 1). Lygus populations in these experiments consisted almost entirely of *Lygus hesperus* Knight.

Cage experiments in 1943 conducted by Romney *et. al.* (1944) showed that this insect reduced the weight and viability of guayule seed by feeding on the immature embryos and causing them to collapse. As the major part of their feeding on the plant was on the developing seeds, a consideration of damage to the seed should serve as an index of the effectiveness of the treatments. The guayule seed (Table 1) was collected from 2 plants near the center of each plot in the Hansen Field and consisted of seed which ripened between June 14 and July 15, and which was in the susceptible stage during the treatment period. Seed from the Wallace tract was obtained by random samples from 100 plants in each plot, and this seed ripened from July to October. Population counts of Lygus were made with a sampling cage described by Hills (1933), and the insect samples were taken from six plants in each plot.

Data in table 1 show that, excepting in the cryolite plot, six applications significantly reduced the nymphal population, but not sufficiently to be considered effective control. Samples taken 2 weeks earlier in both experiments had shown similar contrasts in Lygus populations in the various treatments. There was no sig-

Table 1.—Results from six insecticidal applications in each plot for control of *Lygus* populations on guayule in 1943.

Treatment	In the Mary Hansen Field				In the Wallace Tract			
	Pounds per acre	*Lygus* per plant after 6 dustings (June 18 & 19) *Nymphs*	*Adults*	Seed germination after 12 days[1]	Pounds per acre	*Lygus* per plant after 6 dustings (Sept. 8 & 9) *Nymphs*	*Adults*	Seed germination after 12 days[1]
Dusting sulfur	30.9	4.9	1.3	34.7%	34.8	7.9	2.1	15.0%
Calcium arsenate	16.1	3.7	0.9	38.5	18.5	9.8	1.8	19.6
Calcium arsenate-sulfur (1 to 2)	20.6	4.9	1.2	44.1	22.1	8.2	1.8	19.7
Paris green-sulfur (1 to 8)	21.6	5.5	1.3	36.3	25.5	9.4	2.2	17.3
Cryolite (50%)	19.8	9.0	1.5	26.1	22.1	12.2	1.6	12.0
Checks		11.3	1.9	28.9		14.6	2.4	13.3
Difference required at 5% level		1.9	0.4	7.0%		3.4	[2]	3.1%

[1] After 12 days most seed had germinated but that remaining on the blotters was cut and the good embryos were added to the per cent germination.
[2] Differences not significant.

nificant difference between treatments in the reduction of nymphal numbers in the plots treated with sulfur, or with calcium arsenate, or with the mixtures of sulfur and the arsenicals. When consideration was given to seed quality, however, it was found that seed from the arsenical and the arsenical-sulfur plots was of significantly higher quality than that from the checks or from the cryolite-treated plots. In other words, the effect of the arsenicals or of the sulfur-arsenical mixtures in increasing the percentage of viable seed was greater than the relatively slight decrease in the numbers of Lygus would have led one to expect. The most plausible explanation for this would appear to be that the food requirement of those bugs which survived the arsenical or arsenical-sulfur treatments was reduced because the insects obtained enough poison in their feeding to cause a loss of appetite, but not enough to be lethal. The above information may offer an explanation of why arsenicals and arsenical-sulfur combinations have given better results, when applied under field conditions on cotton, than the reduced hemipterous insect populations would indicate should have been expected.—11–8–44.

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Comparative Effects of Spray and Dust Treatments on European Corn Borer

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Field tests conducted with insecticides at Toledo, Ohio, during several seasons for control of the European corn borer, *Pyrausta nubilalis* (Hbn.), have consistently shown a wide range in the extent of control obtained by spray and dust treatments. The following experiments were conducted to determine what caused this wide range in control by learning how, when, and where the larvae are killed by the two treatments.

Laboratory Tests.—Tests were conducted in the laboratory with dust preparations to determine their effect on newly hatched European corn borer larvae. The dusts were each distributed evenly over a sheet of waxed paper by sliding a small quantity back and forth, and then holding the sheet in a vertical position so the excess dust would slide off. Very little dust remained on the waxed sheet. In some of the tests the sheets were then sprayed with an atomizer and dried, to simulate conditions in the field after the occurrence of dew or rain. Egg masses in the blackhead stage on small discs of waxed paper were pinned above each sheet. As the eggs hatched, the larvae spun down onto the treated paper below.

Ground derris root containing 4 per cent of rotenone, and mixtures of this with pyrophyllite to make dry dusts containing approximately 1.00, 0.75, 0.63, 0.50, 0.33, and 0.25 per cent of rotenone, were tested in the first experiment.

The effects of the dusts on the larvae were as follows: The ground derris root without pyrophyllite killed the larvae practically on the spot where they landed. The other materials used varied only slightly in their effect on the distance the larvae crawled before they were killed, and no larvae crawled as far as 2 inches. All readily crawled off an undusted sheet of waxed paper.

In another experiment ground derris root containing 4 per cent of rotenone, a mixture of the ground root and pyrophyllite containing 1 per cent of rotenone, and pyrophyllite alone were applied to sheets of waxed paper and also tested as dry dusts in the manner described above. All larvae were killed by all three treatments, the ground derris without pyrophyllite killing them where they came in contact with it, the 1 per cent rotenone killing them before they had crawled 1 inch, and the pyrophyllite without derris killing them before there were able to crawl off the sheet, although some crawled 3 inches.

In a third experiment the same materials were dusted on waxed papers, sprayed with an atomizer, and then dried before the egg masses were pinned over the sheets. In this experiment a few larvae were killed by the ground derris root without pyrophyllite but many crawled off the sheet, all larvae were killed before they could crawl off the sheet treated with the pyrophyllite dust containing 1 per cent of rotenone, and practically all were killed before they could crawl off the sheet treated with pyrophyllite alone.

The results of these laboratory experiments indicate that dusts containing from 0.25 to 4.00 per cent of rotenone in the form of ground derris root cause 100 per cent mortality of newly hatched larvae when the dusts have not been wetted and dried, but that pyrophyllite without any toxic agent causes higher mortality than pure ground derris root containing 4 per cent of rotenone after both dusts have been wetted and dried. Apparently this is because the root powder without pyrophyllite remains caked after having been wet, thus permitting the small larvae to crawl freely over the surface, whereas pyrophyllite tends to return more or less to the powder form when it dries, and seriously interferes with the progress of the larvae when they try to crawl across it. Observations made through a low-power microscope showed that as the larvae crawled across the dusted sheet the dust particles adhered to their appendages and setae. The larvae tried by twisting and turning to dislodge these particles, and the greater their effort the more dust they accumulated.

The larvae killed by the pyrophyllite alone probably died from exhaustion and desiccation. With rotenone mixtures, death was probably due to these factors

plus the insecticidal action of the rotenone. The mechanical effect of the dry dust particles apparently is a more important factor in the death of the young larvae than are small differences in rotenone content, such as that between 0.5 and 1.0 per cent of rotenone. This would explain the findings of Batchelder *et al.* (1937) that a dust containing 0.4 per cent of rotenone caused as high borer reduction in the entire plants as those containing 0.6 and 0.8 per cent of rotenone. It appears logical to assume that dusts would be more effective when applied to plants that are dry than to those that are wet, and also that one could expect higher control from dusts in a year when there is little rain or heavy dew during and immediately following the period of application.

FIELD TESTS.—In one of the three fields in which experiments were conducted on a commercial scale during 1943 with insecticides for the control of the European corn borer, dissections of corn plants were made in a plot to which spray containing 0.0396 per cent of rotenone for two applications and 0.024 per cent for the other two applications was applied on June 20, 25, 28, and on July 5; in a plot to which a mixture of ground derris root and pyrophyllite dust containing 0.5 per cent of rotenone at the rate of 50 pounds per acre per application was applied on June 18, 23, 29, and on July 6, and in an untreated plot. All sprays and dusts were applied with a combination sprayer-duster at the same rate of ground speed. Areskap was used at the rate of 1 pound to 300 gallons of water in the sprays. No wetting agent was added to the dusts. Five plants from each plot were dissected daily from June 21 to July 13, inclusive, except on June 27 and on July 3, 4, and 11. Rainfall during this period was as follows; June 28, 0.65 inches; July 3, 1.30 inches; July 6, 1.45 inches; and July 10, 0.18 inches. The objectives of these dissections were to determine (1) what instars were killed, (2) at what locations on the corn plants the dead larvae were found, (3) the comparative numbers of dead and living larvae found on the treated and untreated plots, and (4) the relation of rainfall and temperature to mortality of larvae.

In both treated and untreated plots most of the mortality occurred during the first instar, with practically none after the third instar in any plot (table 1). The mortality in the untreated plot, however, was apparently somewhat more gradual than in the treated plots. The greatest loss of larvae normally occurred during the early instars while they were attempting to establish themselves on the plant. As observed by the writer and also by Huber *et al.* (1928), this loss was not due to lack of nutrition in the plant but to the inability of the small larvae readily to find suitable feeding places on the plant, and consequently to their dropping from the leaves on which they were crawling. Many of them spun a strand of silk and sailed to the ground, or were blown off the leaves by the wind and were unable to reach other plants before they died.

Table 1.—Mortality of European corn borer instars after spray and dust treatments, and percentage of total number of dead larvae found that died in each instar. Field insecticide experiment, Toledo, Ohio, 1943.

INSTAR	TOTAL LARVAE WHICH DIED AFTER TREATMENT					
	Spray		Dust		None	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
First	1627	95.54	743	93.46	36	90.0
Second	54	3.17	29	3.65	0	0
Third	18	1.06	23	2.89	4	10.0
Fourth	3	.17	0	0	0	0
Fifth	1	.06	0	0	0	0
Total	1703	100.00	795	100.00	40	100.00

The locations on the corn plants at which the dead larvae were found are given in table 2. In the spray treatment the highest percentage of dead larvae, 90, was found between the leaf and stalk. The locations showing the next highest percentages were on the outer leaf and on ear shoots and ears, with 83 and 79.5 per cent, respectively. In the dust treatment the highest percentage of dead borers, 74, was found on the exposed, unrolled leaf surface, indicating that probably in crawling over dry dust particles most of the larvae in the dusted plot were killed by becoming so entangled with the silk which they spun and with the dust particles that they could crawl no farther. This condition has been demonstrated on numerous occasions in the laboratory, both on sheets of waxed paper and on greenhouse-grown corn plants. The percentages of larvae killed by the dust in the whorl, between the leaf and the stalk, and in the ear-shoot loca-

Table 2.—Percentages of European corn borers found in different locations on corn plants after spray and dust treatments, and percentages of total in each location that were found dead. Field insecticide experiment, Toledo, Ohio, 1943.

Location on Plant	Per Cent of Borers (Living and Dead) Found in Each Location			Per Cent of Borers Found Dead in Each Location		
	Sprayed Plot	Dusted Plot	Untreated Plot	Sprayed Plot	Dusted Plot	Untreated Plot
In whorl	17.1	18.1	19.7	64.3	34.5	1.7
In tassel	14.1	14.7	21.9	23.7	4.9	0
On outer leaf	31.4	22.4	7.9	83.0	74.0	5.9
Between leaf and stalk	29.7	24.2	20.9	90.0	47.4	1.2
On ear shoot and ear	7.0	18.5	25.9	79.5	33.7	.2
Inside stalk	.7	2.1	3.7	0	0	0

tions were only about half as high as those of larvae killed by the spray, showing the low lethal effect of dust in these interfoliar spaces. The outer leaf was the only location at which the percentage of mortality caused by the dust approached that caused by the spray. The lowest percentage of kill for both spray and dust treatments was in the tassel, as might be expected, owing to protection afforded the larvae by leaves rolled around developing tassels on some plants, and to the difficulty of penetrating the pollen sacs with either spray or dust. In this location, however, the spray was more than four times as effective as the dust in killing the borers.

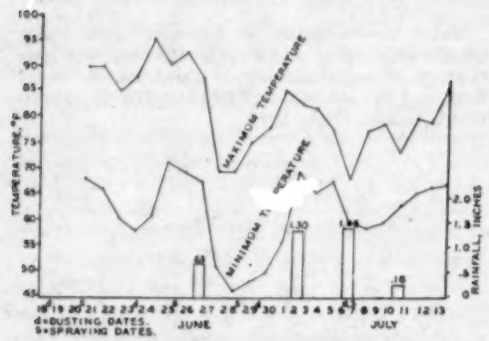

Fig. 1.—Rainfall and maximum and minimum temperatures for the period during which corn-plant dissections were made for counts of European corn borer larvae after spray and dust treatments. Field insecticide experiment, Toledo, Ohio, 1943.

The numbers of living and dead larvae, respectively, found on the plants from the treatments were 634 and 1703 for the sprayed plot, 1154 and 795 for the dusted plot, and 3622 and 40 for the untreated plot. While it is possible that more dead larvae were washed off the plants by rain and therefore lost in the dusted plot than in the sprayed plot, owing to the difference in location on the plants where the larvae were killed, such differences are considered to be so small that they do not materially affect the interpretation. This may partially account for the fact that only 1949 larvae were found on the plants from the dusted plot, as compared with 2337 found on those from the sprayed plot. Only about 1 per cent of the larvae counted in the untreated plot were dead. The higher survival of larvae in this plot is apparent in the cumulative total of 3662 larvae obtained from a summation of the daily counts.

Some information was obtained on the relation of rainfall and temperature to mortality of the larvae. The highest mortality in the sprayed plot occurred on June 29, when 250 larvae, an average of 50 per plant, were found dead following a spray application on the preceding day. High temperatures preceding this application had caused abundant hatching (Fig. 1). Nearly three-fourths of an inch of rain fell shortly after the application was made on June 28, and this may have been partially responsible for its high effectiveness, as it no doubt carried some of the insecticide to larvae hidden in the leaf whorls and other interstices.

High borer mortalities in the dusted plot did not seem to be associated with rainfall. This may be partially accounted for by the fact that a large percentage of the larvae killed by the dust die far out on the leaf, whence rains wash them to the ground instead of into the leaf whorls where they can be found. In addition, the lethal effect of dust is lowered by wetting, as has been demonstrated by the laboratory experiments described earlier in this paper.

Spray residues remained effective longer than dust residues. As shown in figure 2, during the 7 days following the last application of dust and spray on July 6, the percentage of dead larvae found daily in the sprayed plot remained fairly constant, while the percentage found dead in the dusted plot dropped rapidly.

As shown in figure 3, the numbers of living larvae present after the spray and dust treatments indicate that, although the applications were well timed to coincide with the hatching period, control became less effective as the corn neared maturity, especially in the dusted plot. There was little difference in the control effected by the two treatments during the first 2 weeks of the period of infestation, when the corn was a little over 2 feet tall and in the whorl stage. At the approximate end of the hatching period on July 13, however, the corn was fully tasseled and the cumulative number of surviving larvae was 1154 for the dust treatment, as compared with only 634 for the spray treatment.

SUMMARY.—Field tests conducted with insecticides at Toledo, Ohio, during several seasons for control of the European corn borer have consistently shown a wide range in the extent of control obtained with spray and dust treatments. Laboratory and field experiments were conducted to determine what caused this wide range in control by learning how, when, and where the larvae were killed by each of the treatments.

In the laboratory experiments all pyrophyllite dusts containing from 0.25 to 4.00 per cent of rotenone in the form of ground derris root, applied to sheets of waxed paper, caused 100 per cent mortality of newly hatched larvae deposited thereon when the dusted sheets had not been wetted and dried. On sheets similarly dusted and then wetted and dried to simulate the effect of dew or rain, pyrophyllite alone caused higher mortality than straight derris dust containing 4 per cent of rotenone, apparently because the derris dust remained caked, whereas the pyrophyllite again became dusty after drying and so interfered with the progress of the larvae that they died from exhaustion and desiccation before they could crawl off the paper. The physical condition of the dust evidently was a more important factor in its efficiency than was its rotenone content.

In the field experiment dissections of the corn plant were made in a plot sprayed with derris, in a plot dusted with derris, and in an untreated plot. These dissections were begun a few days after the first application and were continued daily, whenever possible, until approximately a week after the last application.

These plant dissections show the following results: (1) Approximately 99 and 97 per cent of the larvae killed by the spray and dust treatments, respectively, died before they reached the third instar. (2) The spray killed a high percentage of larvae on the outer leaves and in the favorite feeding places of the young borers, such as in the whorl, between the leaf and the stalk, and in the ear shoots. Although the dust killed nearly as high a

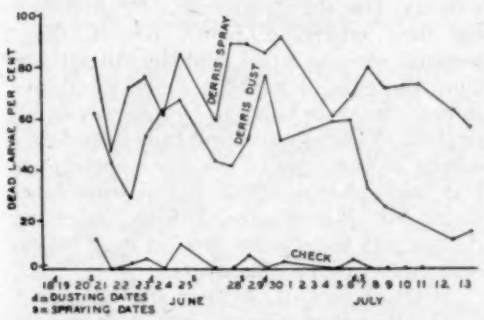

FIG. 2.—Percentages of European corn borer larvae found dead in daily corn-plant dissections after spray and dust treatments. Field insecticide experiment, Toledo, Ohio, 1943.

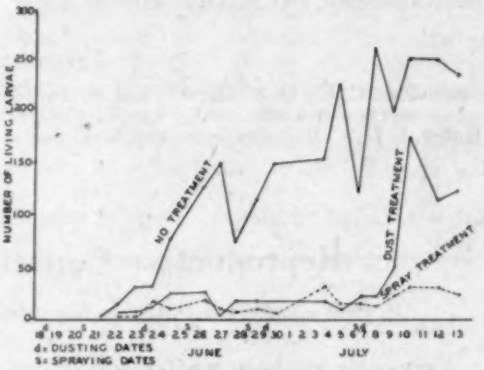

FIG. 3.—Numbers of living larvae of the European corn borer, second instar or older, present after spray and dust treatments. Field insecticide experiment, Toledo, Ohio, 1943.

percentage on the outer leaves, it was only about half as effective in the more protected locations mentioned and less than one-fourth as effective in the tassels. (3) More than twice as many dead larvae were found in the sprayed as in the dusted plot, and over 40 times as many as in the untreated plot. (4) Nearly twice as many larvae were found surviving in the dusted plot and 6 times as many in the untreated plot, as in the sprayed plot. (5) Rainfall appeared to increase the mortality caused by the sprays but reduced the efficiency of the dusts. (6) Spray residues remained effective considerably longer than dust residues.

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Reproductive Capacity of the Hessian Fly

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Very little has been written concerning the reproductive capacity of the hessian fly, *Phytophaga destructor* (Say). McConnell's paper (1921) was the first detailed account of the egg-laying capacity of this insect and was based on dissections of hessian flies collected in the vicinity of Carlisle, Pa. Other published records are very brief. McColloch (1923), in his life-history work, found an average of 97 eggs per female, with extremes of 0 and 320. Rockwood & Reeher (1933) found that the number of eggs varied considerably, the maximum capacity observed being 361. Other writers (Wade 1934) make only brief mention of egg capacity, the consensus of opinion being that the average number is about 200 eggs per female.

As a part of the investigation of the hessian fly in Kansas and neighboring States, the writer undertook to determine its fecundity. The data on which this paper is based were obtained during the years 1921 to 1925.[1] It is recognized that several factors, such as the intensity of the infestation, the date of sowing, the time of emergence, and soil moisture, influence the number of eggs produced by the females. It is thought, however, that the large number of dissections made over a period of years afforded a basis for a reliable estimate of the reproductive capacity of the hessian fly in the region under consideration. This region was divided into three areas according to the type of winter wheat grown therein, as follows: (1) The soft-winter-wheat area, which included all of Missouri, southeastern Nebraska, the part of Kansas east of Topeka, northeastern Oklahoma, and northwestern Arkansas; (2) the transition area, a narrow belt extending southward from Omaha, Nebr., to Tulsa, Okla.; and (3) the hard-winter-wheat area, which included the territory west of the transition area in Nebraska, Kansas, and Oklahoma.

GENERATIONS AND BROODS.—As a rule, there are two principal generations of the hessian fly in Kansas and adjacent states, namely, the spring generation, produced by flies emerging from overwintering puparia early in April, and the fall generation, the eggs of which are deposited late in September or early in October. A small portion of each generation fails to produce adults at the time of the main emergence but holds over and emerges at some later date. For this reason, adults appearing during any emergence period may represent two or more generations.

METHOD OF COLLECTION AND REARING.—The flies that were dissected in this investigation were reared from puparia collected in the course of the work on date of seeding winter wheat as a control measure, in various localities in Kansas, southern Nebraska, Missouri, northwestern Arkansas, and northeastern Oklahoma. The flies for dissection were divided into the following two main groups: (1) Spring-brood flies reared from puparia of the fall generation, collected in October and

[1] J. S. Pinckney, J. R. Horton, and F. M. Wadley dissected a portion of the flies used in this study.

November, soon after the formation of the puparium. The normal time of adult emergence is in the following spring, but the puparia were kept in the laboratory, thus inducing emergence during the winter months. (2) Fall-brood flies reared from puparia of the first and second spring generations collected from ripening wheat just before harvest in June. It was impossible to separate the puparia of the spring generations taken from stubble collected at harvest time, consequently no distinction was attempted when the dissections were made.

tive capacity, the abdominal volume of each of a large number of adults was computed. The abdomen of a hessian fly adult resembles the geometrical figure known as a parabaloid, the volume of which is determined from the formula $V=(\pi/2)r^2L$, when V is the volume, r is one-half the observed diameter, and L is the length of the abdomen. The diameter and the length of the abdomen were measured with a binocular microscope equipped with an eyepiece micrometer graduated in hundredths of a millimeter. The adults were measured and dissected

Table 1.—A summary of the number of eggs per hessian fly female obtained by dissection of 638 adults, 1921–25.

AREA	DISSECTED	EGGS PER FEMALE		
		Maximum	Minimum	Average
	Number	*Number*	*Number*	*Number*
Spring generation (fall brood):				
Soft winter wheat: Missouri, Arkansas, Kansas, Oklahoma	52	381	122	203
Transition, soft and hard wheats: Kansas	2	223	191	207
Hard winter wheat: Kansas, Oklahoma	19	309	88	211
Total, extremes, and average	73	381	88	205
Eastern flies (McConnell 1921)	160	386	34	233
Fall generation (spring brood):				
Soft winter wheat: Missouri, Kansas, Oklahoma	307	388	36	191
Transition, soft and hard wheats: Kansas, Nebraska	146	368	25	189
Hard winter wheat: Nebraska, Kansas	112	356	31	163
Total, extremes, and average	565	388	25	185
Eastern flies (McConnell 1921)	107	464	33	287

The puparia were put in homeopathic vials, 10 per vial, and the vials were plugged with cotton. The vials were then put in holes bored in plaster of paris blocks, with the plugged end in contact with the plaster. The moisture required was absorbed from the plaster blocks, which were kept moist by setting them in shallow pans of water at intervals of a day or two and allowing the plaster to become nearly saturated. This method of handling the puparia proved satisfactory. In the spring generation there was a high mortality due to parasitization, disease, and desiccation, which accounts for the smaller number of fall-brood flies dissected, as compared with those of the spring brood.

RELATION OF SIZE OF ABDOMEN TO REPRODUCTIVE CAPACITY.—In order to determine whether the size of the female abdomen was indicative of the reproductive capacity, the abdominal volume of each of a large number of adults was computed. The abdomen of a hessian fly adult resembles the geometrical figure known as a parabaloid, the volume of which is determined from the formula $V=(\pi/2)r^2L$, when V is the volume, r is one-half the observed diameter, and L is the length of the abdomen. The diameter and the length of the abdomen were measured with a binocular microscope equipped with an eyepiece micrometer graduated in hundredths of a millimeter. The adults were measured and dissected shortly after emergence, inasmuch as the eggs are fully developed at the time of eclosion and the females survive only 2 or 3 days to lay them, thus making it unnecessary to wait for egg development in the specimens used for study.

The average abdominal volume for 641 adults was 0.96 cubic millimeter, ranging from a minimum of 0.12 to a maximum of 2.12 cubic millimeters, with the number of eggs ranging from 25 in the smallest female to 388 in the largest. The correlation coefficient between the volume of the abdomen and the number of eggs was found to be 0.79 ± 0.121. Thus it was evident that the reproductive capacity is partly dependent on the size of the abdomen.

RESULTS OF THE DISSECTION OF SPRING-GENERATION (FALL-BROOD) FLIES.—The results of the dissection of 73 adults from

the spring generations are given in table 1. These represent the group that oviposits on wheat in the fall. It is against this generation that control by date of seeding is directed. It may be noted in the table that the number of eggs per female dissected in this study was somewhat less than that observed by McConnell (1921) in Pennsylvania.

RESULTS OF DISSECTION OF FALL-GENERATION (SPRING-BROOD) FLIES.—For this generation the data are much more extensive than for the spring generation. The results of the dissection of 565 females are presented in table 1.

In the course of these dissections three females were found in which no eggs were present. Their abdomens were filled with a thin milky fluid in which numerous motile bacteria could be discerned when examination was made under high magnification.

Two principal types of wheat are grown in the region involved (Kansas and neighboring states)—hard winter in the western part and soft winter in the eastern part, with a transition area where both types occur. It is evident from the data that there is a definite tendency toward lessened egg capacity in the hard-wheat area, where the annual precipitation averages less than 33 inches, as compared with the soft-wheat area, where the annual precipitation averages more than 33 inches. The difference between the means of 191 and 163 eggs for the soft-winter-wheat and the hard-winter-wheat areas is highly significant. Applying the *t*-test for significance, *t* has a value of 10.8, a highly significant difference for this number of observations. In comparing the egg capacity of eastern flies, as reported by McConnell (1921), with that of western flies, it appears that, on the average, the reproductive capacity of western flies is considerably less than that of eastern flies.

SUMMARY.—The numbers of eggs present in hessian flies from the hard-winter-wheat area and the western part of the soft-winter-wheat area were determined by dissecting freshly emerged females taken from various localities and broods during a 5-year period and counting the eggs contained in their abdomens.

The abdominal volumes of 641 adults were computed and found to average 0.96 cubic millimeter, ranging from 0.12 to 2.12 cubic millimeters. The number of eggs per female containing eggs ranged from 25 to 388. There was a positive correlation between the number of eggs per female and the volume of the abdomen.

Spring-generation flies were found to have a slightly greater reproductive capacity than those of the fall generation.

There was a definite tendency toward lessened egg capacity in flies from the hard-winter-wheat area and the western part of the soft-winter-wheat area, as compared with those examined from the soft-winter-wheat area of Pennsylvania.
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HAMPTON ROADS ENTOMOLOGY CLUB

Sixteen entomologists and others interested in entomology have organized the Hampton Roads Entomology Club, the chief purpose of which is to promote the efficiency of entomological work in the Hampton Roads area. Informal meetings are planned from time to time especially when outside speakers are available. The officers elected at the January meeting are: president, Dr. Harry G. Walker, Va. Truck Experiment Station; vice-president, Dr. E. Ruffin Jones, Jr., Norfolk Division, College of William and Mary; and secretary-treasurer, Dr. William E. Bickley, U. S. Public Health Service.

A New Plant Insecticide for Control of the European Corn Borer[1,2]

BAILEY P. PEPPER, *New Jersey Agricultural Experiment Station, New Brunswick*, and L. A. CARRUTH, *New York State Agricultural Experiment Station, Geneva*[3]

From the time the European corn borer, *Pyrausta nubilalis* (Hubner), first became a serious pest in northeastern United States, extensive research has been conducted by entomologists of the United States Department of Agriculture and of various state experiment stations in an effort to find effective control measures. The development of techniques and materials for protecting sweet corn with insecticides has received particular attention. One of the earliest discussions of the principles involved is presented by Batchelder & Questel (1931). Working under Connecticut conditions, Batchelder *et al.* (1937) reported effective borer control on early market sweet corn with preparations of derris, phenothiazine and nicotine tannate in spray form and a dual-fixed nicotine dust. Pepper (1938) reported that nicotine-bentonite and derris or cube root gave good corn borer control in New Jersey when used either in sprays or in dusts. Baker & Questel (1939) reported that in Ohio nicotine preparations, whether used as sprays or dusts, were inferior in effectiveness to rotenone-bearing materials and that the latter were more effective in spray form. Before the outbreak of the war progressive corn growers in the areas affected by the eastern two-generation strain of the corn borer had begun the commercial use of insecticides for borer control. Insecticidal dusts had given satisfactory results and, for practical reasons, were preferred over spray treatments. Although dual-fixed nicotine was reported to be more effective than 1 per cent rotenone under Connecticut conditions (Turner 1941; Beard & Turner 1942), the latter, less expensive material gave acceptable results in New York (Carruth 1942) and in New Jersey. With the advent of the war, the manufacture of dual-fixed nicotine dust was discontinued and the available supply of rotenone-bearing insecticides was sharply reduced. During this period encouraging results were obtained with an alternative corn borer dust containing 4 per cent nicotine and prepared from a nicotine-bentonite concentrate containing 14 per cent nicotine (Carruth 1943; Pepper & Haenseler 1944). Acceptable results were also obtained with a dust containing 2 per cent nicotine (from the above source) and 0.5 per cent rotenone. Although a fair degree of corn borer control in market sweet corn can be obtained with one or more of the above insecticidal preparations, a need still exists for a more effective corn borer insecticide, capable of producing dependable results over a wide variety of cultural conditions at a reasonable cost.

During recent laboratory studies conducted by the Merck Research Fellow of Rutgers University, *Ryanex*,[4] a material prepared from tropical plants of the genus *Ryania*, was found to be toxic to certain insects. Exploratory field testing of insecticidal dusts prepared from *Ryanex*, derived from *Ryania speciosa* Vahl., was begun in New Jersey in 1943. In tests against the first summer generation of the European corn borer the results were so favorable that further tests were made that season against the second generation of borers with equally good results. A small sample of the undiluted material was made available for confirmatory testing against the second 1943 generation of borers in eastern New York, where excellent borer control likewise resulted. This led to the more extensive investigations in New Jersey and New York during 1944 which are reported in the following pages.[5]

This paper consists of the joint presentation of results of field tests of *Ryanex*, conducted independently but along parallel lines, in New Jersey and New York. These tests include comparisons of *Ryanex* with other corn borer insecticides, both as dusts and as sprays, investigations of concentrations, timing of treatments,

[1] Paper of the Journal Series, New Jersey Agricultural Experiment Station, Rutgers University, Department of Entomology.

[2] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 612, December 8, 1944.

[3] Costs of publication of this paper have been assumed by Merck & Co., Inc.

[4] A product of Merck & Co., Inc. A descriptive discussion of the insecticidal properties of *Ryanex* will appear in a forthcoming paper by Dr. R. E. Heal.

[5] These studies were supported in part by Merck & Co., Inc.

rates of application, diluents, and performance under commercial conditions.

METHODS AND TECHNIQUES.—In New Jersey the 1943 and 1944 field tests against the first summer generation of borers were located at Englishtown in a level, 12-acre field planted to Marcross 13.6 hybrid sweet corn both years. The second generation tests were conducted at Milltown in a different field each season, both fields being planted to Lincoln hybrid sweet corn. In accordance with the practice prevailing among New Jersey growers the corn was drill-planted and thinned to one plant per hill. All tillers, or suckers, were removed leaving only one central stalk per plant. The 1944 field tests in New York were conducted at North Syracuse, Onondaga County, in Columbia County and in Nassau County. First generation tests were conducted in fields planted to several of the better early market sweet corn hybrids. Second generation tests were conducted principally in plantings of Golden Cross Bantam hybrid sweet corn. With one exception, all New York test fields were drill-planted and thinned to approximately one plant per foot of row. The tillers were not removed from the plants in the test fields except on Long Island, where it is the prevailing agricultural practice, and in one series of plots in Columbia County where relationships between rate of insecticide application, borer populations and tiller removal were under investigation.

In the two states similar systems of plot arrangement were used. Except as noted, the standard arrangement for each treatment consisted of four replicates, each four rows wide and 30 to 50 feet long, which were laid out in randomized blocks.

Except as noted, the treatment schedules consisted of four successive applications at 5-day intervals for the New York tests and the first generation New Jersey tests. A fifth application was standard for the second generation New Jersey tests. Treatments were ordinarily begun shortly after the first borer eggs in a given field had begun to hatch in appreciable numbers.

Insecticides in dust form were tested in New Jersey while in New York both spray and dust applications were made. All dust mixtures in both states were prepared in *Messinger* non-balling dust mixers.[1] All applications of dusts to the small replicated plots in both states were made with bellows-type "American Beauty" knapsack dusters. Sprays were applied as described below.

Record-taking at harvest was affected by the supply of labor available. From 10 to 25 plants per replicate, or from 40 to 100 plants per treatment were completely dissected. In most of the tests reported below, 50 plants per treatment were dissected from the center of the inner rows of the replicates in 12-13-12-13 order. Records were made of the numbers of borers present in the stalks, tillers (New York only) and full-sized ears. Borers in ears smaller than salable size were considered as part of the stalk infestations. In the following tables the infestation data are summarized in terms of total "borers per 100 plants." This value, in the New York data, includes infestations in tillers except as specially noted. The yields of full-sized ears were graded for borer infestations, injury and salability according to the "U. S. Standards for Green Corn" established by the Agricultural Marketing Service of the United States Department of Agriculture. Only ears grading "U. S. No. 1" or "U. S. Fancy" were considered salable.[2] In the following tables all ears falling in these two grades were combined and designated as the "salable yield." Full-sized ears not meeting these standards were considered unsalable.

Because of differences in cultural conditions, sweet corn plants, even from the same lot of seed, tend to be larger in upstate New York than in New Jersey. This is reflected in the larger quantities of insecticide per acre which are required to produce a degree of corn borer control in New York comparable to that produced in the generally smaller plants commonly found in New Jersey.

PRELIMINARY TESTS IN 1943.—In a small non-replicated field test against the first summer generation of borers in New Jersey in 1943 *Ryanex*, applied as an undiluted dust, gave much better control than 0.5 per cent rotenone dust. In more elaborate, replicated tests against the

[1] All dust mixtures containing rotenone or *Ryanex* also contained 0.2 per cent of the supplement *Vatsol OS*.

[2] A ruling by the New York State Commissioner of Agriculture and Markets states that only sweet corn meeting the grade requirements of U. S. No. 1 or U. S. Fancy may be legally sold in the state.

second generation of borers *Ryanex*, diluted to 50 per cent strength with *Loomis* talc and applied for the usual schedule of 5 treatments, produced a 99.2 per cent reduction of borers in the plants. During the previous seven years of insecticide testing against this insect in New Jersey the most effective materials usually gave only 70 to 75 per cent reduction in borer population under practical conditions. It is considered that the control afforded with *Ryanex* on second generation borers in 1943 was the most effective ever produced up to that time under New Jersey conditions. In addition, the size and weight of the ears in the *Ryanex* treated plots were much superior to those in the rotenone or nicotine treated plots.

Ryanex was first tested in New York against the second 1943 generation of borers in Columbia County. In a field where untreated sweet corn averaged 2700 borers per 100 plants small plots, liberally dusted with 5 applications of undiluted *Ryanex* at 5-day intervals, averaged 8 borers per 100 plants at harvest. This degree of control was outstandingly better than that found in nearby plots treated with several other of the standard insecticidal dusts.

COMPARISONS WITH OTHER INSECTICIDES.—In 1944 *Ryanex* was compared more extensively with other insecticides, both in spray and dust form. This work is summarized in tables 1 and 2. Table 1 summarizes results of dusting experiments in New Jersey and New York in which *Ryanex* dusts are compared with dust mixtures containing nicotine, rotenone and DDT. A standard *Ryanex* preparation, derived from *Ryania speciosa* Vahl., was used for the tests in both states. The New Jersey treatments were made at the rate of approximately 40 pounds per acre per application. In New York, where larger plants with tillers were present, the treatments averaged from 50 to 60 pounds per acre per application in these tests, in which it was sought to determine the comparative degree of control obtainable by various dust mixtures applied under particularly favorable dosage conditions. All treatments were applied 4 times at 5-day intervals except the second generation New Jersey plots which received 5 dust applications. The first generation New York test was located at North Syracuse while the second generation test was located in Kinderhook township, Columbia County.

Table 2 summarizes the results of two 1944 spray tests in Columbia County, New York in which *Ryanex* was compared with cube, nicotine-bentonite and DDT. Sprays were applied by a 2-row portable boom, equipped with 3 nozzles per row,

Table 1.—Relative effectiveness of insecticidal dust mixtures used in field tests against the European corn borer in New Jersey and New York during 1944.

	New Jersey				New York			
	Generation				Generation			
	First		Second		First		Second	
Dust Mixtures Used	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable
Rotenone 1%[1]	176	84.0%	138	76.8%	35	100%	252	91.7%
Rotenone 0.5%[2] Nicotine 2%	170	88.2	—	—	78	92.5	226	79.5
Nicotine 4%[3]	100	94.1	96	81.6	195	97.3	282	65.3
DDT[4] 3%	74	96.0	76	81.9	135[5]	88.0[5]	76	98.1
Ryanex[5] 50%	39	98.7	12	94.8	90	92.3	38[7]	98.4[7]
Untreated	1119	40.0	823	20.1	788	26.2	826	51.1

[1] Rotenone source: cube root; New Jersey diluents: sulfur 25%, balance *Loomis* talc; New York diluent: pyrophyllite (*Pyrax ABB*).
[2] Rotenone source: cube root; nicotine source: nicotine-bentonite (14% nicotine); New Jersey diluent: sulfur 25%, balance *Loomis* talc. New York diluent: pyrophyllite (*Pyrax ABB*).
[3] Nicotine source: nicotine-bentonite (14% nicotine); New Jersey diluents: sulfur 25%, balance *Loomis* talc (0.2% *Vatsol OS* added). New York diluent: walnut shell flour, 200 mesh; no supplement was added.
[4] DDT source, New Jersey: Merck & Co. 80% DDT in *Pyrax ABB;* this preparation was diluted to 3% DDT with additional *Pyrax ABB;* 0.2% *Vatsol OS* was added. DDT source, New York: duPont 10 per cent DDT dust concentrate diluted with *Loomis* talc to a DDT strength of 3%; no further supplement was added.
[5] Due to insufficient material which arrived late this treatment was not replicated. Only the last 3 dust applications were made.
[6] Diluent: *Loomis* talc.
[7] These values are from an adjoining test in the same planting and are to be compared with untreated plot values of 930 borers per 100 plants and 40.0 per cent ears salable.

with hose connections to a small, trailer-mounted, power sprayer operating along the side of the field. The boom was carried by two men. Sprays were applied under 150 pounds pressure at an average rate of 175 gallons per acre per application. Four applications were made at 5-day intervals. *Ryanex* and cube (4 per cent rotenone)

Table 2.—Relative effectiveness of insecticidal spray mixtures used in field tests against the European corn borer. Columbia County, New York, 1944.

Sprays Used	First Generation		Second Generation	
	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable
Ryanex 4–100	115	97.2%	62	100.0%
Cube 4–100	85	81.8	100	89.1
Nicotine-bentonite 3–100	156	45.7	404	35.3
DDT 1–100	35	94.7	32	100.0
Untreated	725	21.6	820	44.9

sprays were prepared at the rate of 4 pounds per 100 gallons of water with 2 ounces of the proprietary material *B-1956* added as a supplement. Nicotine-bentonite, containing 14 per cent nicotine, was prepared at the rate of 3 pounds per 100 gallons, without further supplement, as recommended for the spraying of fruit trees. DDT (duPont 25-per cent DDT spray concentrate, with supplement) was used at the rate of 4 pounds (1 pound of actual DDT) per 100 gallons without further supplement.

An examination of table 1 indicates that 50 per cent *Ryanex* dust gave better control than dusts containing rotenone or nicotine except in the first generation New York test where the control was essentially comparable to that produced by these materials. In spray tests (table 2) *Ryanex* gave equal or better control when compared with cube and both were definitely superior to nicotine-bentonite at the concentrations used. Tables 1 and 2 also indicate that *Ryanex* was essentially equal in effectiveness to DDT at the concentrations used in these tests.

Concentration Studies.—The favorable results in 1943 with undiluted and 50 per cent *Ryanex* dusts indicated the desirability for determining the lowest concentrations at which this insecticide could be effectively used under field conditions. During 1944 the performance of various concentrations of *Ryanex* was tested in both New Jersey and New York. These tests are summarized in table 3. In all cases *Loomis* talc was used as the diluent. The standard schedule of 4 applications at 5-day intervals was followed except in the second generation New Jersey tests where 5 applications were made. Dusts were applied at an average rate of 40 pounds per acre in New Jersey and 50 pounds per acre in New York. The first generation New York test was located at North Syracuse and the second generation test was located in Columbia County.

Despite the wide variations in insecticide concentrations a generally high level of ear protection was maintained. Differences in total borer populations in the plants were more in accord with the changes in insecticide concentration. Until further tests are possible under a wide range of infestations and cultural conditions the optimum range of *Ryanex* concentration in corn borer dusts should probably be considered for the present to

Table 3.—European corn borer control with dusts containing various concentrations of *Ryanex*, 1944.

Insecticide Concentration	First Generation		Second Generation	
	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable
New Jersey data:				
10 per cent	192	97.1%	—	—
20 per cent	134	98.0	64	100.0%
30 per cent	64	100.0	30	84.6
40 per cent	32	100.0	24	89.7
50 per cent	36	96.0	12	94.8
Untreated	1119	25.2	823	20.1
New York Data:				
10 per cent	200	79.1%	256	89.1%
25 per cent	148	93.9	140	96.6
50 per cent	90	92.3	28	98.2
Untreated	788	26.2	930	40.0

lie between the 30 and 50 per cent levels even though indications of effectiveness at lower levels are present. Experience with other insecticides emphasizes the folly of using corn borer insecticides at too low a concentration when heavy infestations of borers may be expected. No data are available on the relative effectiveness of various levels of *Ryanex* applied in spray form.

TIMING OF APPLICATIONS.—The accepted procedure in the insecticidal control of the corn borer on sweet corn has been to make at least four successive treatments to a given planting, starting shortly after the first corn borer eggs have begun to hatch in appreciable numbers. At the time of the first treatment most sweet corn plantings have averaged from 18 to 24 inches in height. By the final application plantings have frequently approached their maximum height. In evaluating a new insecticide, such as *Ryanex*, it would be helpful to learn whether the usual schedule of 4 to 5 treatments at 5-day intervals could be shortened to any extent without appreciable loss of borer control and, if so, which treatments are most important. The results of two tests to determine the relative value of various applications of *Ryanex* are summarized in table 4. In both cases 50 per cent *Ryanex* dust, diluted with *Loomis* talc, was applied. In New Jersey treatments were made at an average rate of 40 pounds per acre per application while in New York the average rate was 50 pounds per acre per application. The treatment dates were June 9, 16, 22 and 27, 1944 for a first generation test in New Jersey and August 5, 10, 15, 20 and 25, 1944 for a second generation test in Columbia County, New York.

The data in table 4 serve to emphasize the inherent toxicity of *Ryanex* since all treatments gave extremely high percentages of salable ears and relatively low borer populations in the plants. It is indicated, however, that the latter applications are probably more efficient than the early ones. This is also borne out in a second generation New Jersey test where the last 3 applications gave practically as good control as a full schedule of 5 applications. The relatively poorer performance of the 1 per cent rotenone dust in the New Jersey test is worthy of note. In previous experiments the application of rotenone and nicotine dusts in incomplete schedules of treatments resulted in poor control of corn borers.

The 1944 investigations also included tests in which the intervals between applications of *Ryanex* dust were lengthened from the 5-day standard to 7 and 10 days. The results of these tests are summarized in table 5. Fifty per cent *Ryanex* in *Loomis* talc was used. The New York test was located in Columbia County. Application rates were the same as above. In those cases where the interval between treatments was lengthened the first treatment was made in every instance on the starting dates of the standard application schedules.

Table 4.—Corn borer control produced by the application of 50 per cent *Ryanex* dust for various numbers of treatments within the standard schedule of 4 to 5 treatments at 5-day intervals.

Periods at Which Treatments Were Made	New Jersey Data		New York Data	
	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable
3rd	84	100.0%	—	—
4th	216	86.0	—	—
1st, 2nd	146	100.0	—	—
2nd, 3rd	118	98.0	—	—
3rd, 4th	68	100.0	—	—
1st, 2nd, 3rd	110	98.0	64	97.8%
2nd, 3rd, 4th	42	98.0	22	100.0
3rd, 4th, 5th	—	—	24	97.9
1st, 2nd, 3rd, 4th	36	96.0	42	96.4
2nd, 3rd, 4th, 5th	—	—	10	100.0
1st, 2nd, 3rd, 4th, 5th	—	—	12	100.0
1 per cent rotenone, 4 applications	176	84.0	—	—
Untreated	1119	25.2	376	86.8

From table 5 it will be observed that the degree of ear protection from the plots dusted for fewer treatments at longer intervals between treatments was essentially equal to that found in plots receiving the normal schedule of treatments at 5-day intervals. The borer populations in plants receiving two treatments at 10-day intervals were higher than those in the other treated plots although about equal to the populations frequently encountered in plots receiving a full schedule of the standard nicotine or rotenone dusts.

DOSAGE STUDIES.—To evaluate further the effectiveness of *Ryanex* against the corn borer tests were made in New Jersey and New York in which a 50 per cent dust, diluted with *Loomis* talc, was applied to sweet corn plantings at different dosages per acre per application for the standard schedule of 4 treatments. To study the effect of the tillers, or suckers, on the degree of borer control obtained at various dosage levels, a double series of plots was used in the New York test, conducted in Columbia County. In one series of plots the tillers were left undisturbed, in accordance with the prevailing local practice. In a second series of plots the tillers were removed, as is the common practice on Long Island and in New Jersey. This was done prior to the first application

Table 5.—Corn borer control produced by lengthening the interval between *Ryanex* treatments and reducing the number of applications below the normal schedule of 4 to 5 treatments at 5-day intervals, 1944.

Dust Treatments Made	Days Between Treatments	New Jersey Data				New York Data	
		First generation		Second generation		Second generation	
		Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable	Borers per 100 Plants	Ears Salable
5	5	—	—	12	94.8%	—	—
4	5	48	100.0%	—	—	58	98.2%
4	7	82	100.0	62	96.2	—	—
3	7	—	—	—	—	108	96.2
2	10	148	98.0	—	—	228	92.2
Untreated		1119	25.2	823	20.1	626	70.9

period. The tillers were also removed in the test plots from which the New Jersey data are taken. The results of these tests are summarized in table 6.

Table 6.—Corn borer control produced by 50 per cent *Ryanex* dust applied at different rates per acre per application, 1944.

Pounds per Acre per Application	Borers per 100 Plants	Ears Salable
New Jersey data, first generation: (tillers removed from all plants)		
20	124	100.0%
25	70	100.0
30	60	100.0
35	50	100.0
40	32	100.0
Untreated	1124	25.2
New York data, second generation:		
a. plants with tillers present		
20	132	79.6%
35	62	97.9
50	62	98.1
Untreated	384	77.3
b. plants with tillers removed		
20	220	90.7%
35	108	97.7
50	40	100.0
Untreated	528	69.0

From table 6 it is evident that in the New Jersey tests that there was a break in the efficiency of the dusts between the ranges of 20 and 25 pounds per acre. The higher dosages reduced the borer populations in the plants still further while even the lowest dosage produced a yield of completely salable ears.

From the New York data it is also evident that a dosage of 20 pounds per acre was less effective than the next higher dosage. Good ear protection was obtained at the 35 and 50 pound levels, with no appreciable difference in effectiveness between these dosage rates, whether tillers were present or absent. The higher borer population in the plants from which the tillers were removed indicates that the main stalks received many of the eggs which might otherwise have been laid on the tillers where a lower rate of survival may have existed. This test was conducted in a planting of Golden Cross Bantam sweet corn. Further tests of this type are planned with other corn varieties under heavier infestation conditions.

Table 7.—Corn borer control obtained with four different diluents for 40 per cent *Ryanex* dust mixtures, 1944.

Diluent	Pounds Used per 100 Lbs. of Finished Dust	Borers Per 100 Plants	Ears Salable
Loomis talc	60	24	89.7%
Pyrophyllite (*Pyrax ABB*)	60	42	83.7
Tobacco powder	60	28	82.4
Loomis talc plus Sulfur	25 35	24	86.7
Untreated	—	823	20.1

DILUENT STUDIES.—In the tests summarized above, *Loomis* talc was used as the standard diluent for *Ryanex*. In New Jersey, during the period of the second borer generation of 1944 the performance of *Ryanex* at 40 per cent strength was compared when prepared with four common diluents. As with all other *Ryanex* dust mixtures mentioned in this paper, 0.2 per cent *Vatsol OS* was added as a sup-

plement to each mixture. The diluent comparisons are summarized in table 7.

From table 7 it is evident that under the conditions of this test 40 per cent *Ryanex* was essentially of the same effectiveness regardless of which diluent was used. In relation to the infestations in the untreated plots the differences in effectiveness between the different mixtures were probably too slight to be of real significance.

TESTS UNDER COMMERCIAL CONDITIONS.—A standard 50 per cent *Ryanex* dust, diluted with Loomis talc and containing 0.2 per cent *Vatsol OS* was used in New Jersey in 1944 on commercial plots of sweet corn varying in size from 0.5 to 1 acre on three farms against the first generation of borers and on two farms against the second generation. Power row-crop dusters were used for four of these tests and a hand operated duster for one test. Rotenone and nicotine-bentonite dusts were used as bases for comparison. In all five cases the *Ryanex* dust was superior in effectiveness to the nicotine-bentonite and the rotenone dusts. The per cent reduction in borer population with *Ryanex* averaged from 87 per cent to 94 per cent. Each cooperating grower expressed a desire to use this dust on early maturing sweet corn in the future. Preliminary tests in New York in which 50 per cent *Ryanex* dust was applied to commercial sweet corn plantings with power-operated, wheelbarrow and knapsack dusters also provided a high degree of European corn borer control.

SUMMARY.—*Ryanex*, a hitherto unreported insecticide of plant origin, prepared from the tropical plant *Ryania speciosa* Vahl., was tested against the European corn borer under field conditions in New Jersey and New York during 1943 and 1944. In preliminary tests in New Jersey during 1943 the corn borer control produced by *Ryanex* was considered the most effective ever obtained up to that time. In preliminary tests in New York in 1943 undiluted *Ryanex* produced a degree of borer control that was outstandingly better than that in nearby plots treated with other insecticides. More extensive comparative tests in 1944 in both states indicated that a 50 per cent *Ryanex* dust was more effective than previously used dusts containing nicotine and rotenone, except in one New York test where the degree of control was essentially comparable to that produced by the latter materials. Spray tests in New York indicated that *Ryanex* gave a degree of control equal to, or better than, that produced by cube. *Ryanex* was essentially equal in effectiveness to DDT under the 1944 test conditions. Pending further testing the optimum range of *Ryanex* concentration in corn borer dusts should probably be considered for the present to lie between the 30 and 50 per cent levels although indications of effectiveness at lower levels are present. Preliminary estimates indicate that a 50 per cent *Ryanex* dust can compete in cost with a 1 per cent rotenone dust. When the normal application schedule (4 to 5 insecticide treatments at 5-day intervals) was modified by reducing the number of treatments and by lengthening the interval between treatments all partial schedules tested gave high percentages of salable ears and low borer populations when 50 per cent *Ryanex* dust was used. It was indicated that the latter treatments may be more necessary than the earlier ones. When 50 per cent *Ryanex* dust was used at various rates of application there appeared to be a break in efficiency in New Jersey between the ranges of 20 and 25 pounds per acre per application. Although higher dosages reduced borer populations even further, an excellent degree of ear protection was obtained when a dosage as low as 20 pounds per acre was used. In New York a dosage of 20 pounds per acre was less effective than a dosage of 35 pounds per acre. Good control was obtained at the 35 and 50 pound levels in New York with little difference in effectiveness between these rates, whether tillers were present or absent. No appreciable differences were observed in the performance of 40 per cent *Ryanex* dust mixtures prepared with four common diluents. The 50 per cent *Ryanex* dust applied to commercial plantings with power dusting equipment and with smaller dusters provided an excellent degree of practical control in New Jersey tests and in preliminary trials in New York.[1]—12-14-44

[1] The helpful interest of Dr. R. E. Heal of the Research Laboratories of Merck & Co., Inc., is gratefully acknowledged. The assistance of Mr. Robert S. Filmer and Mr. Fred Eden in the New Jersey investigations and of Mr. John J. McKelvey, Jr. and Mr. L. M. Bartlett in the New York investigations is appreciatively recognized.

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Effect of Weather on *Cochliomyia americana* and a Review of Methods and Economic Applications of the Study

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This article, which is a review of part of the work begun by the author about 1916 to determine the effects of weather and climate on insect activities and populations, may be of general interest in studies of insect populations, control, and abatement.

METHODS AND EQUIPMENT.—Uniform methods and equipment were developed for all procedures. From variables obtained in the use of these uniform procedures, factors affecting the development, activity, and populations of the screwworm fly were determined, as well as from variables discovered in developing the procedures. This will be discussed further under the separate heads of procedure.

PROCEDURE IN STUDYING WEATHER FACTORS.—Since the Weather Bureau had established uniform procedures for making weather records and had recorded climatic data for the entire United States, these procedures and records were used in the screwworm studies. The basic guide in climatic and weather studies has been the work of Baker (1936).

The subject in hand is basically the reaction of the screwworm to low temperatures. Air temperatures have two regularly recurring cycles—diurnal and annual. Both these cycles complete more or less regular undulations of temperature. The extremes, high and low, of each daily undulation are measured and the mean and the extremes of these daily undulations are the basis for measuring the annual undulations. Over a period of years, daily mean temperature variations are greater than monthly, and monthly are greater than annual variations. In most parts of the United States temperature changes are rather similar at any one time in localities within a radius of 40 to 500 miles or more.

Temperatures at any place will almost certainly fall within the range of extremes established for that place over a period of 20 or more years. The author has used this hypothesis as a basis for applying Weather Bureau data to studies of insect populations and development. After the response of an insect to temperatures is established for an area, other affecting factors being more or less constant over considerable time periods, insect activity within the area can be predicted with some degree of certainty from temperature and other weather trends.

ESTABLISHING FLY-POPULATION TRENDS.—The method of establishing the trend of the screwworm fly population was developed over a 20-year period. The first methods used were counts of flies at carcasses and on wounds, observations of fly infestation in livestock, and miscellaneous trappings. The present uniform trapping method was established in 1931. Results obtained from these uniform trap-

pings coordinated well with weather records for the several species of blowflies. Although the weather and fly populations over areas with radii of approximately 40 miles or more coordinated for each trapping period, it was found that the catches varied greatly as between traps only a few feet apart when the traps were in different environments. A uniform trap environment was therefore established.

Notwithstanding this care in the placement of traps, the trapping results still did not coordinate well with case incidence and severity of screwworm attack on livestock, and this discrepancy was found to be due to the confusion of *Cochliomyia macellaria* (F.) with the closely related but then undetermined species *C. americana* established by Cushing & Patton in 1933. In 1935, characters were found by which rapid and accurate field determinations could be made of the primary screwworm fly, *C. americana* in both adult and larval stages. Since that year the numbers of screwworm flies taken in traps have been determined to be good indices to case incidence and severity of attacks of this fly on livestock in any area.

In the present trapping method use is made of standard cone traps (18 inches in diameter and 24 inches high), each baited with 2 pounds of beef liver in 5 quarts of water in an enameled bait pan. The baited traps are usually set from 20 to 40 or more miles apart and in ecological environments representative of the region. When thus spaced there are from 2 to 10 or more traps in each area of a particular ecological and weather type. The findings from these traps are checked by reported incidence of cases in livestock for each area. The traps are serviced twice each month, usually near the fifteenth and the last day of the month. One man usually services about 30 traps in a circuit of from 500 to 1000 miles, and records the fly catch. When less than 5 quarts of flies are taken in a trap, the number of primary screwworm flies included is determined from an actual count. When a trap contains more than 5 quarts of flies, the total number of primary screwworm flies present is estimated from the number counted in a 5-quart sample. When no primary screwworm flies are found in a 5-quart sample, the entire catch is examined to determine the presence or absence of the fly.

FLY ACTIVITY, HABITS, AND DEVELOPMENT.—*Cloth Cages.* Cages were constructed of tobacco shade cloth stretched over light wood frames and were of any desired size. They were first used in studies of the tobacco budworm, *Heliothis virescens* (F.), in Florida in 1913 and have been used since for studies of several other insects. They were located in an environment suited to development of the screwworm fly, and as nearly natural conditions as feasible were simulated in them. Each cage was stocked with a known number of any desired stage or stages and was continued in use from generation to generation of the insect or for any desired period. The purpose in the use of these cages was to study, under as nearly natural conditions as feasible, the development, habits, and continuity of a fly population. The results obtained in the cages were confirmed by field studies. The cages used in the overwintering studies of the screwworm fly were 12 feet on each side and from 6 to 7 feet high. The frame was made of 1-by-2-inch strips fastened to a continuous base of 1-by-12-inch boards set 6 inches in the soil. The cages were set over pasture soil with as many native plants inside as possible, and food and host material were supplied for all insect stages. The fly activities in the cages were fairly comparable with those in the field.

Field Recovery Cages. The cages used for field recoveries were made with sides of 1-by-12-inch boards and were 3 feet square and covered with 16-mesh metal cloth. The board frame base was set 6 inches deep in the soil. These cages were used to determine the developmental period and percentage of adult emergence from mature larvae dropped naturally or planted on different soil types and soil covers—stony, sandy, or clay soils; cultivated or pasture lands; and bare or with grass, manure, leaf, or other cover as might be found in areas in which studies were made. From 100 to 500 mature larvae were planted in each cage setting. The cages were set up at the cessation of fly activity in the field and again during the cool season when fly activity in the field was indicated during the warmer periods.

Metal-Cloth Cages. Other, cylindrical cages were constructed of 16-mesh metal cloth and were 2 feet high and 10 inches in diameter with a removable top or a small, cone-trap top of wire screen. They were used to cover mature larvae or

newly formed pupae planted at regular intervals during the cool season. The larvae were dropped on top of the soil in the cage and the pupae were buried 2, 6, 10, and 20 inches in the soil so that information might be obtained as to outcome when larvae are dropped from wounded animals in shallow animal burrows. Usually 50 to 100 of either larvae or pupae were planted in each cage.

Cave and Animal Burrows. Throughout the parts of the United States infested by the screwworm fly many caverns and caves are found. Some of these are several miles long and extend hundreds of feet below the surface of the earth. Most of the area is also infested by burrowing animals of several species susceptible to attacks of the screwworm fly. Larvae and pupae of the fly were planted in these caves and burrows at intervals during the cool season, and observations were made to determine whether the screwworm flies visited or inhabited these caves and burrows during winter months.

ASSEMBLING AND COMPUTING DATA.[1]—The data presented have been taken from original notes and from manuscripts filed at Uvalde, Tex., and Tempe, Ariz., which include also summaries of reports and manuscripts giving data from other laboratories. All the experiments were executed from a work outline prepared by the author of this section, and all methods and equipment were the same as those used at Uvalde, with some slight modifications to permit the use of equipment available at other laboratories. The basis of this summary has been the observed and recorded reaction of many millions of flies. Several thousand pages of tabulated data have been consulted, and more thousands of tables, charts, and graphs of data have been prepared. As far as possible, discrepancies in data were traced back to the original notes, and incomplete and conflicting data have been eliminated. These summaries are based on the condensed extremes and means of totals in the original records, in so far as it was feasible to determine or present them.

Data have been computed on a monthly basis as far as feasible for the reason that the recorded weather data had been summarized on that basis. The yearly cycle has been used as beginning with the first of any month. Practically all data have been reduced to a uniform scale of 100 units between extremes (Parman 1940).

DISCUSSION OF DATA.—Table 1 presents average daily mean temperatures and rainfall on a monthly basis and indicates whether *Cochliomyia americana* overwintered each year at the several laboratories.

These data indicate that the average daily mean temperature determined whether or not *Cochliomyia americana* overwintered each year at each place, and fixed the determining daily mean averages for the period December, January, and February at near 49° F. as the minimum limit for overwintering. The lowest mean temperature during these months at which the fly overwintered was 49.2° and the highest mean temperature at which they did not overwinter was 50.3°. The daily mean temperature marking the survival limit for the 5-month period was fixed at near 53° F., as the lowest mean temperature at which they overwintered was 53.3° and the highest mean temperature at which they did not overwinter was 53.8°. A study of all data at hand indicates that the populations of the fly usually decrease when the monthly average of the daily mean falls below 60°, other factors being more or less favorable.

No instance has been found in any area in the United States where the fly remained continually present in which the annual average of the monthly means of temperature was below 67° F. For shorter periods than 3 months the average daily mean temperature is not so reliable as an index to the trends of the fly populations and activity, and shorter periods than this are necessarily studied as nonrecurring shock factors.

More than 200 other factors have been found to limit or totally exterminate populations of *Cochliomyia americana*. In the data presented, none of these factors are indicated to have materially affected the statement as to whether some individuals of the fly overwintered, but some of these factors are noticeably operative on the percentage of the population that overwinters.

The average trend of populations of *Cochliomyia americana* during the cool period of 7 years at Uvalde, Tex., as de-

[1] Data have been collected at laboratories of the Bureau of Entomology and Plant Quarantine and by employees of this Bureau as follows: Uvalde, Tex., D. C. Parman, R. A. Roberts, Ralph Conner, A. W. Lindquist, C. C. Deonier, R. W. Burgess, H. M. Brundrett, W. L. Barrett, Jr., E. E. Lester; Tempe, Ariz., C. C. Deonier; Sonora, Tex., O. G. Babcock; Menard, Tex., H. E. Parish; Dallas, Tex., E. W. Laake, Roy Melvin, Raymond Bushland, C. L. Smith; Valdosta, Ga., and Gainesville, Fla., A. L. Brody and E. E. Rogers.

Table 1.—Weather data of various places in relation to winter activity of *Cochliomyia americana*.

Place and Year	Nov.	Dec.	Jan.	Feb.	Mar.	Average Nov.–Mar.	Average Dec.–Feb.	Lowest Temp.	Date	Overwintered
GAINESVILLE, FLA.										
1935–1936										
Mean temperature..	65.5	50.2	56.9	57.0	64.0	58.7	54.7	23	Dec. 21	Yes
Rainfall.....	0.67	1.97	3.97	7.88	2.78	3.46	4.61			
1936–1037										
Mean temperature..	61.6	59.5	58.8	58.7	61.2	59.9	59.0	26	Nov. 28	Yes
Rainfall.....	0.10	2.63	3.32	4.60	3.03	2.74	3.52			
1937–1938										
Mean temperature..	60.5	55.8	56.6	62.8	69.5	61.0	58.4	20	Dec. 7	Yes
Rainfall.....	3.88	1.76	1.90	2.24	1.38	2.23	1.97			
1938–1939										
Mean temperature..	65.9	56.0	59.1	65.5	67.0	62.7	60.2	26	Nov. 28	Yes
Rainfall.....	0.74	0.53	1.84	5.70	1.01	1.96	2.69			
VALDOSTA, GA.										
1935–1936										
Mean temperature..	59.5	45.7	51.5	50.4	59.4	53.3	49.2	20	Dec. 27	Yes
Rainfall.....	0.75	1.64	5.45	4.97	2.15	2.99	4.02			
1936–1937										
Mean temperature..	56.9	54.2	64.4	55.3	57.2	57.6	58.0	23	Nov. 28	Yes
Rainfall.....	0.10	5.43	1.04	3.85	5.72	3.23	3.44			
1937–1938										
Mean temperature..	56.6	51.0	52.5	60.1	65.9	57.2	54.5	17	Dec. 7	Only in cage
Rainfall.....	3.73	1.37	1.37	.87	1.95	1.86	1.20			
1938–1939										
Mean temperature..	61.7	51.5	57.3	62.1	64.1	59.3	57.0	22	Feb. 24	Yes
Rainfall.....	1.05	2.44	3.18	6.92	1.60	3.04	4.2			
DALLAS, TEX.										
1934–1935										
Mean temperature..	59.6	48.4	49.2	49.5	62.4	53.8	49.0	8	Jan. 21	No
Rainfall.....	5.01	.88	3.33	2.16	0.74	2.42	2.12			
1935–1936										
Mean temperature..	51.8	44.8	43.8	42.0	62.6	49.0	43.5	10	Feb. 18	No
Rainfall.....	1.67	0.90	0.48	0.28	0.90	0.85	0.55			
1936–1937										
Mean temperature..	52.2	50.3	41.9	49.0	51.2	48.9	47.1	19	Jan. 9	No
Rainfall.....	0.74	2.17	1.50	0.28	4.51	1.84	1.32			
1937–1938										
Mean temperature..	52.4	46.5	48.8	54.2	63.8	53.1	49.8	19	Jan. 31	No
Rainfall.....	4.56	5.40	6.34	4.73	4.40	5.09	5.49			
1938–1939										
Mean temperature..	54.1	48.1	50.7	45.6	59.6	51.6	48.1	18	Feb. 21	No
Rainfall.....	1.14	1.00	2.75	4.35	2.49	2.35	2.90			
MENARD, TEX.										
1935–1936										
Mean temperature..	53.7	46.7	43.9	48.0	59.9	50.4	46.2	18	Feb. 18	No
Rainfall.....	1.0	1.1	0.2	0.2	0.4	0.6	0.5			
1936–1937										
Mean temperature..	50.8	48.6	43.4	47.5	50.5	48.2	46.5	15	Jan. 23	No
Rainfall.....	0.8	0.9	0	0.3	1.4	0.7	0.4			
1937–1938										
Mean temperature..	56.4	46.2	48.9	48.1	63.5	52.6	47.7	20	Jan. 31	No
Rainfall.....	1.2	4.9	2.1	1.8	0.3	2.1	2.9			
1938–1939										
Mean temperature..	51.7	46.2	49.3	47.8	61.2	51.2	47.8	16	Feb. 19	No
Rainfall.....	0.4	1.7	2.5	0.5	0.9	1.2	1.5			
SONORA, TEX.										
1935–1936										
Mean temperature..	56.8	48.4	47.2	50.0	61.2	52.7	48.5	18	Feb. 18	No
Rainfall.....	0.5	1.2	0.4	0.1	0.8	0.6	0.6			
1936–1937										
Mean temperature..	51.6	51.0	47.8	52.2	54.2	51.4	50.3	16	Jan. 23	No
Rainfall.....	0.5	0.7	0.2	0.3	0.4	0.4	0.4			
UVALDE, TEX.										
1935–1936										
Mean temperature..	60.1	52.6	50.6	55.6	65.1	56.4	52.3	19	Jan. 19	Yes
Rainfall.....	0.3	2.9	0.3	0.1	1.6	1.0	1.1			
1936–1937										
Mean temperature..	57.5	54.5	52.0	57.0	58.0	55.8	54.5	28	Dec. 15	Yes
Rainfall.....	1.1	0.5	0.9	0.1	1.5	0.8	0.5			
1937–1938										
Mean temperature..	59.5	52.0	54.0	60.0	68.5	58.8	55.3	22	Nov. 20	Yes
Rainfall.....	0.2	6.0	2.1	0.7	1.7	2.1	2.9			
1938–1939										
Mean temperature..	59.5	54.5	54.0	53.5	66.0	57.5	54.0	25	Nov. 8	Yes
Rainfall.....	0.0	1.2	1.5	0.3	0.2	0.6	1.0			
1939–1940										
Mean temperature..	57.5	55.0	43.9	53.5	62.9	54.6	50.8	17	Jan. 19	Yes
Rainfall.....	2.0	1.1	0.1	2.3	1.4	1.4	1.2			
1940–1941										
Mean temperature..	59.0	56.8	55.6	53.7	56.5	56.3	55.4	27	Nov. 13	Yes
Rainfall.....	2.5	3.6	1.1	3.9	3.8	2.9	2.9			
1941–1942										
Mean temperature..	59.9	54.3	51.0	54.0	61.7	56.2	53.1	20	Jan. 11	Yes
Rainfall.....	0.5	0.4	0.2	1.3	0.2	0.5	0.6			
TEMPE, ARIZ.										
1936–1937										
Mean temperature..	59.1	51.0	41.6	52.8	57.8	52.5	48.5	20	Jan. 22	No
Rainfall.....	0.6	2.3	1.6	0.7	2.2	1.5	1.5			
1937–1938										
Mean temperature..	57.5	54.1	52.7	54.6	57.4	55.3	53.8	28	Jan. 111	Yes
Rainfall.....	0.0	0.8	0.4	0.8	0.9	0.6	0.7			

termined by trap catches for each month, is, for October, 291; November, 65; December, 130; January, 75; February, 5; March, 6; and April, 95. Attention is called to the marked decrease of adult flies taken in November. The reason for this is the very marked drop in temperature from a daily mean 20-year average of 72.4° F. for October to a 59.0° average for November. At Uvalde the maximum change was in 1938, when the daily mean temperature for October, 74.0°, dropped to 59.5° F. in November, and the trapped adults dropped from 187 in October to 4 in November. The minimum change was in 1936, from 66.0° in October to 57.5° in November, and the adult fly catch dropped from 156 to 135.

Adult life is short—about 2 weeks—when the daily mean temperature is above 70° F., and the shock of cold nights following warm days kills a high percentage of the population. Adults surviving these shocks and adults emerging during cooler periods live for longer periods in the cool season—about 1 month or longer. The pupal stage is about 10 days at 75°, 15 days at 70°, and 30 days at 60°, with the duration about 20 per cent longer or shorter when influenced by other ecological factors. Normally there is an almost complete cessation of emergence early in November, and the pupal period then extends over into some warm period in December or January.

In order that the effect of factors such as rainfall and temperature on the populations of the screwworm fly may be better studied, table 2 presents the daily mean temperatures for Uvalde, Tex., and Tempe, Ariz., for the 5-month period November to March for different years, these being arranged in the order of increasing temperature, the ratio of adult flies taken in November and December to those taken in February and March in status traps, and the average monthly rainfall at Uvalde and Tempe.

Line No. 1 (Table 2) is eliminated from any study of overwintering, as the fly did not overwinter in any part of Arizona (or in California) during that season. From lines 2 to 6 the average daily mean temperature for the 5-months' period increased from 54.6° to 56.3° F. in steps of approximately 0.5 degree, excepting between lines 5 and 6. Lines 5 to 7 have nearly the same average daily mean temperature, but they have the extremes of winter survival. The ratio of carry-over in the Uvalde trap (line 5) was 83:0; in 5 other traps plus the Uvalde trap the ratio was 76:1. These three lines also have the extremes and near mean of the rainfall presented in table 2. While the extreme low rainfall of line 5 is near that of line 3, the data for line 3 are from a large area of irrigated pastures, whereas line-5 data are from a non-irrigated area. In 1938–39 there was a very low overwintering of the fly in the vicinity of Uvalde. A 5-months' period with 0.5 inch of rainfall per month is indicated as near the minimum rainfall limit of toleration for the fly.

With the higher extreme of rainfall, 2.9 inches per month, the survival was very low, but in line 9 with 2.1 inches per month it was near the highest carry-over and survival was also recorded at Gainesville, Fla., and Valdosta, Ga., with over 3 inches of rainfall per month. The factor of type of rainfall was probably operative. The rainfall for the period in line 6 was slow, misty, and continuous. The same type of rainfall prevailed for the month of December in line 9, but rain was inter-

Table 2.—Degree of reduction of *Cochliomyia americana* populations during winter and effect of the rainfall factor: Five-month period November to March, inclusive, at Tempe, Ariz., and Uvalde, Tex.

Line No.	Place	Year	Nov.–March Temperature (°F.)		Flies Taken in Traps					Flies Taken in Trap Nov.–Dec.	Ratio of Flies Taken in Nov. and Dec. to Those Taken in Feb. and Mar.	Average Monthly Rainfall (Inches)
			Daily mean	Min.	Nov.	Dec.	Jan.	Feb.	Mar.			
1	Tempe	1936–37	52.5	20	62	13	0	0	0	75	75:0	1.5
2	Uvalde	1939–40	54.6	17	94	364	14	6	2	458	57:1	1.4
3	Tempe	1937–38	55.3	28	49	18	3	2	2	67	17:1	0.6
4	Uvalde	1936–37	55.8	28	135	214	178	24	4	349	12:1	0.8
5	Uvalde	1941–42	56.2	20	80	3	5	0	0	83(304)[1]	83:0(76:1)[1]	0.5
6	Uvalde	1940–41	56.3	27	29	209	79	1	1	238	119:1	2.9
7	Uvalde	1935–36	56.4	19	12	111	237	3	18	123	6:1	1.0
8	Uvalde	1938–39	57.5	25	4	12	1	0	0	16	16:0	0.6
9	Uvalde	1937–38	58.8	22	101	0	14	0	14	101	7:1	2.1

[1] Six traps in Uvalde area.

mittent in the other months. This is reflected in the trap catch of December (line 9) instead of the usual increase over that of November. This will be discussed later in the overwintering of different stages of the fly.

When the data are charted and extended on an annual-cycle basis for the Uvalde type of climate and weather, the limits of tolerance of *Cochliomyia americana* to rainfall are indicated as approximately a minimum of 0.4 inch and a maximum of 5 inches per month. The highest annual populations have developed when the monthly average rainfalls were between 1.5 and 3 inches per month.

Many other factors affecting the overwintering of the fly are reflected in the data presented. The more important of these are the numbers of the fly at the beginning of the winter period, the type of host material, and temperature and rainfall types rather than averages. Most of these factors were operative for short periods and to a great extent were lost in averages.

WINTER HABITS AND ACTIVITIES.—There are many factors that affect the day-to-day development, habits, and activity of the several stages of the fly. Little or no coordination of development or activity with any of these factors can be shown for these short periods, although the extremes which cause total arrest of development or activity may be determined. Toleration limits for the fly must be established before preventive or control measures are undertaken or attempts are made to change population trends over longer periods.

HABITS OF ADULTS.—The adult screwworm flies have never been observed to seek protection from cold either while in cages or under natural conditions. They usually rest on low vegetative growths or other objects from near the ground to about 10 feet high, some drop to the ground when the air temperature falls below freezing, and all have usually dropped by the time 20° F. is reached. Some fallen flies will revive and begin to show life if the temperature rises to 45° within a few hours, and they will crawl or fly back to their perches when the temperature reaches 50° to 55° if factors are favorable.

Feeding and normal life activities begin at approximately 60° F. Few flies revive after being subjected to temperatures of 20° and none have survived from lower temperatures. The percentage of dropped flies making normal recovery rises from approximately 1 per cent or less at exposure to 20° to 90 per cent at 32°. As has been stated, abrupt and sudden changes in temperature are usually fatal to a high percentage of the adults. Such temperature changes are frequent in the Southwest, the daily range being as much as 70 degrees or more. Daily ranges of as much as 40 to 50 degrees markedly shorten the life of the adult when minimum temperatures are below 30° F.

Adults are normally inactive at night. Normal activity begins soon after sunrise and ends shortly after sunset. They seek the lightest areas in cases and usually the brightest sunshine under natural conditions, except at high temperatures, when they seek light shade. They are less active on cloudy days and become inactive with heavy clouds. They have never been found resting in buildings, caves, burrows, or any deep shade; but they do visit these places to oviposit, and natural oviposition has taken place in the almost complete darkness of a small coop in a goat shed on a bright, hot day. The flies will enter rather heavily shaded areas to some extent to feed. For these reasons the trends of the screwworm fly population may tend to be higher in areas or during winters with a high percentage of sunshine than in places or times with less sunshine. (See Uvalde data, table 2, lines 6 and 7. The period covered by line 6 had 38 clear days and that by line 7 had 76 clear days.)

Adult fly activity is retarded by winds of 5 or 6 miles per hour and is prevented by winds as high as 15 miles per hour. For this reason more adults are taken in traps in brush areas than on prairies or open plains. The fly does not inhabit heavy, dense forests. Other factors being equal, the areas with highest overwintering ratios are rolling to rugged, and brush covered. Catches in traps located one above another indicate that the adults are more active near the ground and do not enter traps in the tops of the highest brush cover. The ratios at Uvalde were approximately as follows: On ground, 50 adults; 4 feet above, 10; and 12 feet above ground, 2. At 18 feet above ground none were taken in mesquite trees approximately 25 feet high. Charts recording

average wind movements on areas where the screwworm fly occurs throughout the year show the effect of wind on its overwintering. Valleys and brush cover provide windbreaks to a considerable extent, especially near the ground. Adults are seen and are taken in traps in open areas on days with little wind movement. During winter periods small, open, sunny areas usually have more active adults than brush areas.

Rainfall and moisture affect the adult markedly. Adults are inactive during continuously rainy periods. Referring to the record for Uvalde, for December, 1937 (Table 1), no adults were taken in the status trap during the month, and yet a nearly normal population was indicated in the preceding month. No heavy rains fell during the month until December 29, when a fall of 2.27 inches was recorded, but there was almost continual slow, misty rain on 25 other days of the month. Compare these data with those of December 1935 at Uvalde, 11 days with rainfall in two distinct periods, and those of December 1936 at Tempe, Ariz. (Table 1).

In the cloth cages at Uvalde adults lived through December 1937 to January 18, 1938, but were inactive practically all the month of December and no oviposition was obtained during the month, although adults of all ages were in the cage at the beginning of the month. The first recorded oviposition and cases of attack in the field were on January 14, 1938, and only a few additional cases were noted during the next 6 days. This will be discussed further under the subject of pupae.

The adults appear to have their longest life span during cool, moist weather. The maximum life span for an adult, 76 days, was recorded during the winter of 1940–41 at Uvalde. Rather long life spans were recorded at Gainesville, Fla., and one of 61 days at Valdosta, Ga., in 1936–37. Adults confined in a cage without water in some form rarely live more than 2 or 3 hours when temperatures are above 80° F., and not more than 2 or 3 days at the lowest temperatures not lethal to the fly. Moisture also is advantageous in keeping the food supply available. When baits in traps become dry they are not attractive to *Cochliomyia americana*. Animal-carcass baits kept immersed in water have remained attractive more than 6 months. The adults are apparently able to use condensed moisture transpired by plants, or possibly hygroscopic moisture, to maintain life. Adult populations decrease rapidly as plants in an area reach the permanent wilt stage. During extremely dry winters the populations of the fly are maintained only near streams and about stock-watering places.

Adults are always most abundant in areas used by livestock. In some of the desert areas in Arizona, lying between the higher mountain summer grazing lands and the large irrigated valleys used for winter grazing and feeding, the fly was taken only at the time bands of sheep were being moved through these areas in fall or spring.

Adults require a live, warm-blooded animal with a wound or diseased tissue for natural oviposition. With one exception the fly has never been observed to oviposit under natural conditions on other tissue; the exception was an adult that laid its eggs on the head of a sheep about 2 hours after the sheep had been slaughtered and when the air temperature was high. In the laboratory, at high temperatures, well-fed, mature, adult females readily deposit normal masses of eggs on lean meats and other media. In animals subject to attack of the fly, only about 5 per cent as many natural wounds occur in the cool seasons as in the warmer months.

As with many other insect pests, man has provided this insect with hosts and the conditions necessary to build up its numbers, by providing these in abundance during the most critical part of its annual cycle. More than 90 per cent of winter infestations of screwworms are in avoidable man-made wounds in livestock and wild animals (Parman 1941). During the winter months the fly, being less active than during other seasons, requires more readily available host materials for reproduction and survival than when higher temperatures prevail. For this reason a critically low population at the beginning of the winter may not survive. (See table 1, Uvalde 1938–39 and 1941–42.)

CONDITIONS AFFECTING THE EGGS AND LARVAE.—As a rule low temperatures do not materially affect the egg and larval stages of the fly. The egg stage may be slightly prolonged by cold, and in extreme

cases of cold rainy weather incubation is prevented. The normal incubation period is approximately 8 hours, and this period is rarely prolonged to more than 24 hours.

The larvae penetrate more deeply into the wounds during cold periods, and larvae dropping during cool weather tend to penetrate more deeply into the soil. In warm weather they pupate from under very slight cover to more than 2 inches deep. As cooler weather approaches they penetrate hard soils 1 or 2 inches and loose soils to 6 inches or more. Larvae dropping at air temperatures below 40° F. soon become immobile, and unless the soil is warmer than the air they usually pupate or die on the surface of the soil. Larvae dropping at temperatures between 15° and 20° F. usually die. The normal larval stage is from 4 to 10 days, with an average of about 6. The larval stage of the fly can endure 10 days of any low temperatures not fatal to the host.

CONDITIONS AFFECTING THE PUPAE.—The pupal stage of the screwworm fly is affected by innumerable factors, for the reason that under natural conditions the stage is located in diverse environments and has no capacity of choosing or of relocating to better its environment. The best that can be done in this discussion is to give the general effects of varied environments and state some specific cases and results.

Temperature is the controlling factor in the developmental period of the pupae. When mean daily air temperatures drop below 60° F., other factors begin to become more effective in influencing the temperature of the immediate site of the pupa and its development both as to time and percentage of emergence of adults. Pupae held at fairly constant temperatures near 55° rarely produce adults. The lower the moisture content of the media, the higher the percentage of emergence at average daily mean air temperatures between 50° and 60°.

During the winter of 1935–36, characterized by reasonably dry, sunshiny weather, approximately 40 per cent of the larvae introduced into the cages late in November produced adults in from 22 to 45 days. Adults fed and were active in December, both in the cloth cage and in the field, but there was no oviposition until the middle of January, when a rather severe outbreak of screwworm cases occurred in the field.

During the winter of 1937–38, however, which was a wet season, there was no emergence from the larvae or pupae planted late in November, but adults from the October and early November introductions lived to January 18, although they were inactive and fed little. No oviposition was indicated in the field or in cages in December, and only a very few screwworm cases were found in the field from January 14 to 20, 1938.

The lowest average daily mean air temperature at which the pupae have produced adults from larvae on dry range soil was 47.6° F. The lowest air temperature to which pupae have been exposed in dry range soil and produced adults was 17°. They did not survive at 15°. Pupae have rarely survived in frozen soil with a moisture content high enough to freeze the soil solid.

Practically all pupae are in the top 6 inches of the soil, and the temperature of this soil is affected by a multitude of factors such as composition, moisture, sunshine, cover, and exposure. Except when the composition is manure or some material supporting organic combustion to produce heat, soil temperatures follow the trends of air temperatures, and can be quite accurately determined from air temperatures after compensation has been made for the type of soil, exposure, and weather. In a sandy soil with a certain slope, soil temperatures may be taken over a period and these compared with air temperatures during the same period under the different weather types (cloud, sunshine, wind, rainfall, etc.), and this trend of soil temperature may be used in connection with any period of air temperatures.

In table 3 are presented data of soil and air temperatures that indicate trends on the average rolling, brush-covered, sandy-clay soil of southern Texas ranges. These data were obtained near Crystal City, Tex. about 40 miles south of Uvalde. They are for the annual cycle June 1937 to May 1938, with the additional months of November and December 1938, in order that these months may be discussed in connection with the trend of populations.

The temperatures presented in table 3 were taken with thermographs and

Table 3.—Trend of soil temperatures with relation to air temperatures near Crystal City, Tex.

Month and Year	Average and Range of Daily Means								Absolute				
	Air temp. (°F.) (monthly)		Soil temp. at 6 inches (°F.)		Soil temp. at 2 feet (°F.)		Soil temp. at 8 feet (°F.)		Max. temp. (°F.)		Min. temp. (°F.)		Rainfall (inches)
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Air	Soil at 6 inches	Air	Soil at 6 inches	
1937													
June	85.4	26.3	91.8	15.0	88.6	1.1	79.1	1.9	107	104	65	76	3.11
July	84.6	24.0	90.1	16.3	88.7	1.1	80.2	1.4	103	104	68	78	1.28
Aug.	85.5	26.1	92.3	15.4	91.4	1.3	81.9	1.7	110	106	62	74	2.28
Sept.	81.6	20.4	84.1	14.5	86.1	2.2	82.5	1.4	99	103	57	67	8.65
Oct.	67.9	24.8	71.9	15.9	76.6	0.5	81.1	2.1	94	88	46	56	1.62
Nov.	59.4	21.6	60.7	10.7	67.6	0.7	77.2	1.7	92	82	33	49	1.19
Dec.	57.2	24.0	56.4	10.3	62.5	1.3	72.8	1.1	82	68	30	40	0.67
1938													
Jan.	54.4	20.0	53.2	8.8	60.7	1.1	70.0	1.4	85	70	30	41	0.60
Feb.	59.3	28.4	60.0	12.8	63.6	1.5	68.3	2.0	93	77	31	48	0.13
Mar.	62.2	25.0	64.8	13.5	66.9	1.6	68.9	1.8	94	82	31	49	1.33
Apr.	73.2	31.4	76.1	15.0	74.0	1.4	69.8	2.3	104	40	40	56	0.05
May	80.1	26.0	83.0	14.2	81.9	0.8	73.8	2.0	98	96	57	67	3.41
Nov.	61.4	27.6	63.8	13.2	69.9	1.4	80.2	2.0	90	84	27	42	0.86
Dec.	55.0	15.7	52.8	9.7	59.0	1.5	74.7	1.5	77	64	32	42	4.69

the air temperatures were checked with self-recording maximum and minimum thermometers. The data are presented for the use of a reader not acquainted with the trends of soil to air temperatures. They will not be discussed further than to call attention to the effect of rainfall on the trend of soil temperatures in relation to air temperature, especially for the months of November and December 1938.[1]

The temperatures on the surface of bare soils have on the average a much greater daily range than air temperatures. Soils in deep caves and caverns have almost constant annual temperatures, usually from 1 to 5 Fahrenheit degrees above the average mean of annual air temperature.

Caverns, animal burrows, and manure accumulations have never been indicated to be effective in extending the overwintering area of the fly into areas with 3- or 5-month periods of air temperatures below the determined limits of average overwintering temperatures. The percentage of those surviving the winter may have been increased, but, if so, such increase has not been determined to be significant.

There is evidence that animals infested in southern Texas with screwworms and shipped to northern states in late winter and early spring take with them to the northern sales pens mature larvae which are dropped there. These larvae and pupae receive protection from cold that would be lethal on pasture lands, and by the time adults emerge, temperatures are high enough for development and reproduction.

When cold prolongs the pupal stage to more than 40 days the percentage of adults emerging drops rapidly, and rarely more than 1 or 2 per cent emerge after a 50-day period. One of the longest pupal periods ever recorded was from December 12, 1939, to February 27, 1940, 77 days, at Uvalde. In this test larvae had been planted on range soil and emergence began on February 8, 1940, after a period of 58 days with average daily mean air temperature of 47.6° F. The average air temperature from January 16 to 31 was 39°, the mean maximum 52.1°, the mean minimum 26.0°, and the absolute minimum was 17°. The lowest soil temperature recorded was 32°. Nineteen per cent of the pupae produced adults. A pupal period of from 28 to 78 days was reported at Valdosta, Ga., in 1935–36, from the carcass of a goat. A maximum pupal stage of 70 days was obtained from larvae planted in manure, and a maximum of 65 days on range soil and on cultivated soil at Tempe, Ariz., 1937–38.

Moisture does not appear to affect the developmental period of the pupae to a marked degree, but it does affect to a marked degree the percentage of adults emerging from the pupae. As has been stated, pupae withstand the greatest cold in dry media, and as the percentage of the water in the medium increases to the point of saturation the percentage of adults emerging from pupae decreases to zero regardless of the temperature. The

[1] It is the author's opinion that a standardized procedure of taking soil temperatures in several regions of diverse environment for long periods of time would materially advance economic entomology and insect-pest prevention and control.

fly rarely establishes or develops a population in any area with more than 5 inches of rainfall per month and in no area with a slow, continuous type of rainfall above 4 inches per month. In table 1, Valdosta, Ga., data of 1937–38, it is indicated that the fly overwintered in cages, but not in the field. The probable reason was that the fly population had decreased to the critical population point before November, as the 4 months preceding had rainfall as follows: July, 7.32 inches; August, 5.86 inches; September, 6.21 inches, and October, 4.64 inches. The last case of screwworm attack observed in the field was on November 10, 1937, and no other case was observed until June 16, 1938.

At Dallas, Tex., in 1937–38, Laake & Smith used a cloth cage covered with tarpaulin. The earth floor was covered with 6 inches of straw, mixed with cow, goat, and sheep manure, and goats and sheep were kept in the cage. Larvae were planted in the cage as follows: 2000 in November 8–11, 200 in December 20–22, and 3000 in January 10–15. One female emerged January 27 and there was continuous emergence to February 15, totaling 53 females and 33 males. Intermittent emergence continued to May 3 from these larvae, and larvae dropped subsequently. No oviposition was observed or indicated either in cages or in the field.

LIFE SPAN OF A GENERATION.—Experiments in cloth cages to determine the total period from oviposition to the death of the last adult of a population indicates that for a winter generation at Uvalde the period is rarely more than 3 months and is usually about 2.5 months or less. The longest period was that obtained in 1940–41 from 100 larvae, reared in a goat and planted in a screen-cylinder cage, the adults from which were kept in the field in a small wire-screen cage with sugar and water available at all times. Oviposition was observed on November 4, and the larvae dropped from the wound and were planted on range soil November 11. Emergence began December 12 and continued to December 19, when the entire number had emerged. One male and one female lived to February 14, 1941, when the last male died; the last female was dead March 6 and probably died March 5. The total period was 121 days. Allowing 10 days for the egg and larval stages and adding the longest pupal period (78 days) and the longest adult life recorded (76 days), a total period of 164 days would be obtained. From observations, trappings, and cage experiments no such period is indicated in the field. The effective, maximum-generation span in nature is probably less than 100 days.

ECONOMIC PHASE OF DATA.—In areas from 80 to 1000 miles wide and for periods of more than 3 months, the average of weather trends follows the same patterns, and trends of the screwworm fly populations tend to follow weather-trend patterns, other factors remaining constant, for the same periods. This is especially true of annual cycles, or as indicated in data presented for the overwintering period. These trends shift to some extent from central points over shorter periods, and local differences occur. For some seasons or longer periods weather trends are modified over wider areas because of shifts of the major storm tracts or change in their type, size, etc., from the normal. When these changes develop to the extent that longer periods of cold or extremely cold weather prevail in an area, overwintering of the fly is prohibited, as at Tempe, Ariz., in 1936–37. When the weather changes are less, the degree of overwintering of the fly is affected, as at Uvalde.

Livestock management remains more or less fixed in all areas over long periods. Its procedures become established because of climate, lay and use of land, financial customs, etc. Since any radical changes in livestock management might seriously affect the entire economy of the area, any proposed changes should be as slight as possible, should be made gradually and with the cooperation of all concerned, and should affect the fewest possible industries, so that losses to individuals and to the livestock industry may be prevented.

As has been stated, man frequently makes conditions favorable for the development of insect populations. As an example, the sheep and goat industry of southwestern Texas did not have so great a screwworm problem as long as flocks were herded and watched. The labor and predatory-animal factors in sheep and goat production became acute, and animal-proof fences were developed in a rugged, brush-covered grazing area. Sheep released in large ranges of this area would

often not be found and treated after receiving injuries, and consequently high populations of the screwworm fly were built up.

It was found that the highest populations in this area followed a rather long shearing period at a time of the year most favorable to the development of the fly in shear-cut wounds. Sheep and goats are sheared twice each year—spring and fall—in the area, and each period lasts 3 to 4 months. From data at hand it was indicated that high populations of the fly would be prevented to a great extent by shortening the shearing period as much as feasible and making it come slightly earlier in the season. No serious objections were encountered to this program, and in January 1941 it was generally recommended as a part of the ranch management to prevent screwworm attack.

Shearing earlier in the fall season prevented a high population of the fly from carrying over to December and January. Creating a wound-free period from October 1 to January 31 decreased chances for development of a generation of the fly to carry over to spring. This has apparently been reflected in the fly populations, as determined in traps during the winter of 1941–42. A survey as of May 1, 1942, indicated that from 5 to 90 per cent of the sheep owners and all goat owners are complying with the program in the various counties in the area.

Comparable methods have been found advantageous in developing preventive measures for eye gnats, *Hippelates* spp., the sticktight flea, *Echidnophaga gallinacea* Westw., and the fowl tick, *Argas miniatus* Koch. Area distribution and its determining factors have been worked out for several species of blowflies and their parasites and predators. As has been indicated in this review of the ecology of the primary screwworm fly, temperature is the limiting factor in the distribution of all insects, and many other factors either limit or prohibit the distributions of an insect within the area to which the insect is limited by temperature conditions.

SUMMARY.—The normal overwintering of *Cochliomyia americana* is confined by climate to the extreme southern parts of the United States. The adult fly has no well defined resting stage, but development and activity are retarded during cooler months.

Tests of the overwintering of this fly in the states of Florida, Georgia, Texas, and Arizona indicated that the average daily mean temperature for 3- and 5-month periods determined whether the fly overwintered in these areas. The minimum temperature limit for the 3-month period was near 49° F. and for the 5-month period was nearly 53°. Most adults are killed when minimum temperatures fall below 20° F. Practically all pupae are destroyed with minimum temperatures below 15° F. Pupae withstand cold better in dry media than in those moist or wet, and the longest pupal period was 78 days. The lowest average daily mean temperature at which pupae survived was 47.6° F. In this case the minimum period covered was 58 days, and emergence continued for a period to total 77 days; the total emergence from this series in dry range soil was 19 per cent.

Other factors limiting the degree of overwintering of the fly were rainfall, hosts, population of fly at beginning of winter, and many lesser factors. Adults live longest during cool, moist periods. The egg and larval stages of the fly usually are not materially affected by weather.

The actual maximum period of carry-over of one generation was 121 days, and the possible carry-over of combined maximum periods of all stages was 164 days.

Caves, animal burrows, or manure accumulations are not indicated to increase the area of overwintering.

The study indicated that shearing at an earlier and not so extended period in the fall would greatly reduce screwworm cases among sheep.—11-17-44.

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Overwintering of *Cochliomyia americana* at Uvalde, Texas

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For a number of years observations have indicated that cold weather usually causes a cessation of screwworm cases on the Edwards Plateau of Texas and northward. More detailed data by various workers of the Bureau of Entomology and Plant Quarantine have shown also that none of the stages of this fly survived the winters of 1935–36 and 1936–37 at Sonora, Menard, or Dallas, Tex. In line with the present experiments, Barrett (1937) has demonstrated that outlying areas are progressively reinfested by migration from the areas in which the insect has survived the winter.

On account of the many environments in which *Cochliomyia americana* larvae may drop from animals in nature, artificial conditions were arranged at Uvalde, Tex., to simulate a few of the possible natural pupation sites. These took into consideration the larvae falling in native pastures, cultivated fields, bedding grounds of sheep and goats, caves, and animal burrows. The last two of these environments were suggested by the findings (Lindquist 1937) that different wild animals harbor infestations of *C. americana* and may hide in caves and burrows when they become infested.

The present paper includes data accumulated during three seasons and obtained from the following three methods of study: (1) Large cloth cages were used to determine whether the insect could maintain itself throughout the winter; (2) observations were made in the field; and (3) the survival of larvae and pupae was studied in small cages.

CAGE STUDIES, WINTER OF 1935–36.—A lightweight cheesecloth was used to cover cages 12 feet square and 6.5 feet high. The conditions in these cages were arranged to simulate many of the environments under which larvae are dropped in nature, *viz.*, grassy and bare spots, cultivated soil, a manure plot, a hollow log, dead grass, etc. Sugar, beef, honey, and water were continuously supplied for the flies that emerged, and a wounded goat was present in each cage for any flies desiring to lay eggs.

Between November 17 and 22, 1935, such a cage was stocked with about 1000 fully developed larvae as they dropped normally from an infested wound of a goat. This period coincided with that of the last infestations found in animals on nearby ranches. It is estimated that 400 flies emerged intermittently from December 17 to January 5. Except for occasional feeding there was little activity of the newly emerged flies until a warm period permitted oviposition on January 13 and 15. From the dropping of larvae to final oviposition by flies of the following generation, the maximum period covering all stages was 59 days.

In order to learn of the fate of larvae developing from oviposition in January, about 450 larvae were put into another cage from January 16 to 21, 1936. The procedure was synchronized with dropping of larvae on ranches. From this cage an emergence of approximately 3 per cent occurred between March 4 and 13. At the time of emergence infestations were found in wounded animals in the field. The high mortality of pupal or prepupal stages in the cage was probably the result of 2 weeks of cold weather with a mean temperature of 43.9° F.

From these records it is seen that *Cochliomyia americana* was able to maintain itself at Uvalde from November 17, 1935, to March 13, 1936, a period of 117 days, two generations having been involved. The average of the daily maximum temperatures for the period was 66.5° F., for the daily minimum 39.9°, and for the daily mean temperatures 53.2°.

FIELD ACTIVITY, WINTER OF 1935–36.—The study of the activity of the insect in the field consisted of scouting for screwworm cases on various ranches and the use of liver-baited fly traps. At Uvalde the last infestation of *Cochliomyia americana* in 1935 was found in the field on November 18, and no others were positively identified until January 10, 1936,

[1] Acknowledgement is made to D. C. Parman under whose direction the work was accomplished. Other observations and tests at Uvalde were made by H. M. Brundrett, at Sonora by O. G. Babcock, at Menard by H. E. Parish and Roy C. Melvin, and at Dallas by E. W. Laake. C. C. Deonier assisted with the larva-survival tests in 1935–36.

although reports from ranchmen indicated that during the first 18 days of January a minor outbreak of screwworms occurred in Uvalde County. The weather was apparently suitable for screwworm attack, being characterized by clear, hot days, with maximum temperatures up to 90° F., and cool nights, with minimum temperatures as low as 32°.

Most of the ranchmen reported more or less screwworm trouble, and it was estimated that several hundred cases occurred in the county. One ranchman reported 26 cases in 100 head of docked sheep, and from them 5 collections of larvae were identified as *Cochliomyia americana*. Another stockman reported a loss of 25 sheep out of 41 screwworm cases resulting from wounds from docking. Some infestations were large and harbored as many as 1 or 2 thousand larvae and several masses of eggs of *C. americana*.

The dropping of thousands of larvae during this warm period made it possible for at least a small number of pupae to survive until spring. Infestations resulted principally from wounds incurred in docking, marking, and castrating, relegated to this season of the year. Following this adult activity, a 2-weeks' period of cold weather ensued with a mean temperature of 43.9° F. which probably killed a large percentage of the flies. Scouting in February failed to reveal any cases, but on March 5 several infestations were found.

In table 1 it is shown that adult females of *Cochliomyia americana* were caught in a liver-baited fly trap each 15-day period,

Table 1.—Number of females of *Cochliomyia americana* caught in a liver-baited fly trap at Uvalde, Tex., during three winters.

PERIOD	1935–36	1936–37	1937–38
December 1–15	80	7	0
December 16–31	31	207	0
January 1–15	206	174	5
January 16–31	31	4	3
February 1–14	3	8	0
February 15–28	0	14	0
	351	414	8

except from February 15 to 28, 1936, December 1 to 31, 1937, and February 1 to 28, 1938. The largest numbers of flies were caught during the occurrence of screwworm cases in the field. During other periods either the air temperatures reduced activity of the flies or the population was too low to result in many specimens in traps or cases of myiasis.

The study of winter activity of the fly indicated that the species was able to overwinter successfully at Uvalde with an average daily mean temperature for the months of December, January, and February of 52.2° F., which is 2.1 degrees below the average and with an absolute minimum of 19°. Subsequent studies have indicated that if the warm period in January 1936 had not occurred, all stages of the screwworm fly might have perished.

SURVIVAL IN SMALL CAGES, 1935–36.—Pupae were buried at different depths in the soil and in sheep and goat manure in cylindrical screen-wire cages 7 inches in diameter and 24 inches high. The highest percentage of emergence and the shortest pupal period were shown by pupae buried 20 inches deep (Table 2). The lowest percentage of emergence and generally the longest pupal periods were shown by those buried 2 and 4 inches in soil. Normally the larvae burrow only an inch or two below the surface before pupating.

Larvae placed in 1 inch of dry sand in a pint jar November 29 and kept in a screen-wire insectary with a solid roof furnished an emergence of 26.7 per cent at a mean air temperature of 52.7° F. during the developmental period. This lot also furnished the longest pupal period recorded, 55 days. A similar test in January showed 9 per cent emergence at a mean air temperature of 52.1°.

CAGE STUDIES, WINTER OF 1936–37.—Between October 23 and November 30, 1936, a cage was stocked with approximately 3500 fully developed larvae. When the flies emerged they were furnished food and a wounded animal. By December 1 cases in the field were rather rare, and it was felt that the caged material compared favorably with that occurring in nature. In the cage the flies oviposited on the animal on 12 days between December 1 and 18, and on January 8, 20, and 25 and February 11. The progeny from these ovipositions carried over into March, when weather conditions were favorable for their continued activity.

In another large cage 500 grown larvae were dropped onto the soil from November 20 to 25. This cage contained no spaded soil or manure, and the larvae had

a choice of grass sod or bare soil. From January 4 to 19, 50 flies emerged and oviposition took place on February 7. From 175 of the larvae hatched from these eggs an emergence of approximately 45 per cent occurred between March 15 and 20. The period of development from oviposition to the death of the last fly of this generation required 81 days. Allowing 3 days as the probable age of the larvae put in the cage in the fall on November 25, the total overwintering period from lasting from 2 to 3 weeks occurred in midwinter, and flies deposited eggs on injured animals. A large number of larvae dropped and made possible the survival of the species through periods when air temperatures were apparently not favorable for development to the adult stage.

Collections of larvae were made from wounds on December 2, 21, and 28. During a warm period from December 28 to January 16 there occurred in the county an outbreak of cases very similar to that

Table 2.—Emergence of *Cochliomyia americana* adults in cages in which larvae and pupae had been placed under different environments and at different times during the winter of 1935–36, Uvalde, Tex.

Number of Larvae or Pupae and Environment	Date Installed	Depth Buried (inches)	Duration of Immature Stages		Emergence (per cent)	Average of Daily Air Temperatures		
			Min. (days)	Max. (days)		Max. (°F.)	Min. (°F.)	Mean (°F.)
30 pupae per cage, buried in soil	Nov. 27	20	22	22	66.7	68.0	43.6	55.8
		10	27	33	46.7	65.3	42.4	53.8
		6	30	41	33.3	64.1	40.8	52.4
		4	36	36	3.3	63.9	40.9	52.4
		2	39	39	3.3	64.5	40.8	52.6
30 pupae per cage, buried in goat manure	Nov. 27	6	31	31	16.7	64.4	42.2	53.3
		4	31	37	53.3	64.3	41.7	53.0
		2	34	40	63.3	63.9	40.9	52.4
30 pupae per cage, buried in soil	Dec. 21	20	34	35	20.0	67.0	35.9	51.4
		10	No emergence					
		6	No emergence					
		4	No emergence					
		2	No emergence					
30 larvae in 1 inch of sand in pint jar, in open insectary	Nov. 29	1	51	55	26.7	66.3	39.1	52.7
111 larvae in 1 inch of sand in pint jar, in open insectary	Jan. 10	1	49	52	9.0	67.6	36.6	52.1

larvae to last fly, involving two generations, lasted 123 days.

A third cage was stocked with 1068 larvae which were collected mainly from wounds of animals in the field between January 11 and 24. Beginning February 22 and continuing until March 5 approximately 10 per cent of the larvae produced flies. At that time infestations were present in nature.

In all these tests the results indicated that the fly was able to overwinter successfully at Uvalde.

FIELD ACTIVITY, WINTER OF 1936–37.—The activity of the screwworm fly during the winter of 1936–37 was somewhat similar to that of the winter of 1935–36, as a period of warm weather of the previous winter. As in the preceding winter the outbreak was augmented by the presence of thousands of docking, castration, and marking wounds on animals. It was estimated that from 400 to 500 infestations in animals occurred in Uvalde County.

In the field no further cases were located until March 1, 1937. At that time it appeared that the species was again able to increase its numbers and had been able to survive the winter at Uvalde. During December, January, and February the average daily mean temperature was 54.3° F., and the absolute minimum was 28°.

Adult screwworm flies were caught throughout the winter at Uvalde in a

trap baited with decomposed liver, particularly when cases were found to be prevalent in field animals. Forty miles northeast of Uvalde, however, only two flies were caught from January 15 to April 1.

SURVIVAL IN SMALL CAGES, 1936–37.—During the winter of 1936–37 tests were made to determine the ability of larvae and pupae of *Cochliomyia americana* to develop to the active adult stage under different outdoor conditions. A total of 4936 larvae and pupae were exposed in small cages in such manner that at no time between October 31 and March 2 was there a period when larvae and pupae were not present in at least some of the different exposure tests. The tests were similar to the larval and pupal survival tests made during the winter of 1935–36 and are reported in tables 3 and 4.

Some adults emerged from every series of immature screwworms installed during the season of 1936–37.

The minimum period for development from larva to adult was 26 days. The smallest percentage of emergence was during the period having the lowest mean temperatures (52.6° F.), and occurred in a cage in which larvae were placed on cultivated soil.

CAGE STUDIES, WINTER OF 1937–38.—A cage was stocked with 2500 larvae of *Cochliomyia americana* from October 22 to November 26, 1937, at which last date activity in the field had apparently ceased. Emergence occurred intermittently, and adult flies were present in the cage until January 18, 1938. December was wet and cold, and no oviposition occurred in the cage.

A second cage was stocked with 860 larvae, some of which were collected from wounds of animals in the field between January 19 and 28. A 58-per cent emergence occurred, and most of the flies emerged before February 20. These flies were not given an opportunity to oviposit, although it is likely that they would have laid eggs, since the weather conditions were favorable.

FIELD ACTIVITY, WINTER OF 1937–38.—In the fall of 1937 screwworm cases probably occurred to the end of November, although the last positive infestation was observed on November 21. Cases were

Table 3.—Emergence of *Cochliomyia americana* adults in cages in which larvae had been placed under different environments, Uvalde, Tex.

Larvae Placed on—	Number Installed	Date Installed	Date of First Emergence	Minimum Length of Developmental Period (days)	Approximate Emergence (per cent)	Average of Daily Air Temperatures		
						Mean maximum (°F.)	Mean minimum (°F.)	Mean (°F.)
Winter of 1936–37								
Range soil	50	Nov. 27	Jan. 12	46	20	65.3	41.6	53.4
Cultivated soil	50	Nov. 27	Jan. 7	41	35	67.3	42.6	54.9
6 inches of manure in soil	50	Nov. 27	Jan. 4	38	75	66.7	41.7	54.2
Cultivated soil	200	Dec. 10	Jan. 27	48	3	64.9	40.2	52.6
Cultivated soil	200	Dec. 15	Jan. 23	39	75	65.5	41.8	53.7
Range soil	50	Dec. 17	Jan. 25	39	20	65.1	41.7	53.4
Cultivated soil	50	Dec. 17	Jan. 25	39	40	65.1	41.7	53.4
6 inches of manure in soil	50	Dec. 17	Jan. 25	39	36	65.1	41.7	53.4
Range grass	115	Jan. 12	Feb. 20	39	19	66.7	43.0	54.9
Cultivated soil	115	Jan. 12	Feb. 20	39	8	66.7	43.0	54.9
12 inches of sheep and goat manure	115	Jan. 12	Feb. 11	30	47	64.2	42.2	53.2
Cultivated soil	200	Jan. 21	Feb. 17	27	35	66.9	42.0	54.4
Cultivated soil	200	Jan. 27	Feb. 22	26	42	68.5	41.2	54.8
Winter of 1937–38								
Range soil	50	Nov. 25	None	—	—	61.9[1]	43.2	52.5
Cultivated soil	50	Nov. 25	None	—	—	61.9[1]	43.2	52.5
6 inches of manure	50	Nov. 25	None	—	—	61.9[1]	43.2	52.5
Range soil	50	Dec. 22	Jan. 31	40	24	66.6	44.8	55.7
Cultivated soil	50	Dec. 22	Feb. 7	47	14	66.9	45.1	56.0
6 inches of manure	50	Dec. 22	Jan. 24	33	16	66.7	47.2	56.9
Range soil	50	Jan. 17	Feb. 15	29	100	71.7	48.4	60.0
Cultivated soil	50	Jan. 17	Feb. 16	30	90	71.7	48.4	60.0
6 inches of manure	50	Jan. 17	Feb. 10	24	42	71.0	45.5	58.2
Range soil	50	Feb. 14	Mar. 14	28	60	73.0	50.0	61.5
Cultivated soil	50	Feb. 14	Mar. 10	24	84	71.5	48.5	60.0
6 inches of manure	50	Feb. 14	Mar. 14	28	70	73.0	50.0	61.5
Debris-covered soil		Feb. 14	None	—	—			

[1] November 25 to December 31.

reported from January 14 to 19, but no specimens were obtained by the writers until January 20, when larvae of *Cochliomyia americana* were collected. The number of cases was less than during the two previous midwinter infestations, but it was indicated that a greater number of the larvae survived because of favorable weather in February. Authentic infestations were determined on March 13, and it was concluded that the species survived the winter in the vicinity of Uvalde with a mean temperature of 55.5° F. and an absolute minimum of 26° for that season.

A comparison of the adult populations of the species for three winters, as given in table 1, shows a marked reduction in the numbers in 1937–38 from those of the two preceding winters. This was probably due to unseasonably cold weather during the last half of November and most of December, which destroyed considerable numbers of immature forms as well as adults.

SURVIVAL IN SMALL CAGES, 1937–38.—The survival of immature stages during various times of the winter is shown in tables 3 and 4. The first series of larvae and pupae installed November 25 under varying conditions yielded no emergence. All other larval installations, with the exception of one test on debris-covered soil, showed emergence.

TEMPERATURE AND WINTER ACTIVITY.—Repeated observations have shown that *Cochliomyia americana* will oviposit in the field and in cages at air temperatures of 61° to 65° F., but such ovipositions were nearly always preceded by several days having maximum temperatures of 75° or above. One record is at hand of oviposition in a cage at an air temperature of 58°, but this occurred only an hour after the arrival of a cold wave.

An oviposition in the field on January 6, 1936, was preceded by a 36-day period in which the average daily maximum temperature was 62.8° F., the average minimum 41.4°, and the mean 52.1°. The maximum recorded was 79° (1 day) and the minimum 32°. Eleven of the days had maxima of 70° or above, 10 of these occurring during the first 15 days of the period. According to the emergence record of caged material it appears that the flies in the field emerged during December and the first few days in January, and that the average maximum temperature of 62.8° was sufficient to permit egg development. This is the lowest temperature yet ob-

Table 4.—Emergence of *Cochliomyia americana* adults from pupae buried in different ways.

DATE OF INSTALLATION	NATURE OF SITE	1936–37		1937–38	
		Number of pupae	Approximate emergence (per cent)	Number of pupae	Approximate emergence (per cent)
Nov. 25–27	6 in. deep in 12 in. sheep and goat manure	50	10	50	0
Nov. 25–27	2 in. deep in cultivated soil	50	2	50	0
Nov. 25–27	6 in. deep in cultivated soil	50	15	50	0
Nov. 25–27	10 in. deep in cultivated soil	50	20	50	0
Nov. 25–27	20 in. deep in cultivated soil	50	8	50	0
Dec. 10	2 in. deep in cultivated soil	200	1.5		
Dec. 17–22	6 in. deep in sheep and goat manure	50	2	50	24
Dec. 17–22	2 in. deep in cultivated soil	50	24	50	0
Dec. 17–22	6 in. deep in cultivated soil	50	14	50	0
Dec. 17–22	10 in. deep in cultivated soil	50	0	50	0
Dec. 17–22	20 in. deep in cultivated soil	50	6	50	0
Jan. 17	6 in. deep in sheep and goat manure			50	30
Dec. 21	2 in. deep in cultivated soil	200	40		
Jan. 17–21	2 in. deep in cultivated soil	200	5	50	48
Jan. 17	6 in. deep in soil			50	70
Jan. 17	10 in. deep in soil			50	2
Jan. 17	20 in. deep in soil			50	4
Jan. 27	2 in. deep in cultivated soil	200	37		
Feb. 14	6 in. deep in sheep and goat manure			50	60
Feb. 14–15	2 in. deep in cultivated soil	200	75	50	76
Feb. 14	6 in. deep in soil			50	62
Feb. 14	10 in. deep in soil			50	40

served for successful egg development and oviposition.

For successful oviposition the preoviposition period, as observed in cages, requires higher temperatures than does actual oviposition. A factor to consider in oviposition at low temperatures is that the warmth emanating from the host's body probably stimulates egg laying.

Feeding and mating have been observed in cages at temperatures as low as 63° F., but usually 74° to 80° is necessary for much activity.

Adults in cages have been reduced to complete immobility and have fallen to the ground at a temperature of 22° F., but with a rapidly rising temperature they recovered and at 47° were able to return to the top of the cage. Some of these flies oviposited in an incubator after being subjected to artificial heat.

On January 9 and 10, 1937, 65 per cent of the adults in a cage survived 2 days at a mean temperature of 33.7°. A minimum temperature of 19° on January 19, 1936, killed all adults in cages. The adults have never been observed to seek protected places in cages.

Emergence, of necessity, is dependent to a large degree on soil temperatures, which are in turn influenced by air temperatures. Emergence has occurred at 40° F. air temperature, but the soil temperature was 60°. Considerable emergence has been observed at air temperature of 60°.

The soil temperature in a cave about 30 feet underground near Uvalde was fairly constant at 72° to 73° F. Larvae buried in this cave in December 1935 emerged in one-third the time necessary for emergence of pupae buried 2 inches underground outside the cave. On cold days soil temperatures in animal burrows were higher than outside, but on warm days the outside soil was warmer.

TEMPERATURES OF SOIL AND MANURE.—Soil temperatures were taken at 9 a.m. and 2 p.m. daily, when they were approximately the minimum and maximum for the day, during December, January, and February 1935–36 and 1936–37. The readings were taken in the same places, in soil 1 inch deep inside a cloth-covered cage, in a sheep and goat manure plot inside a cage, and in soil outside the cage. Table 5 gives a summary of these temperatures.

The soil temperatures, all higher in 1936–37, vary with the air temperatures. The temperature of the goat and sheep manure ran consistently higher than the soil temperatures. The soil inside the cage was lower in temperature by 1 degree in 1935–36 and by 2.3 degrees in 1936–37, than the soil outside. The lower temperature of the soil inside the cage was probably caused by the shade of the cloth, and this fact may have an important bearing on cage tests with insects that spend part of their life cycle in the soil. Development may be prohibited in a cage when outside conditions would permit activity. Emergence at times was also observed to be somewhat slower in the cloth cages.

A difference in the air temperatures inside and outside a cage was also noted. When the sun is bright the inside temperature may be as much as 8 degrees higher. When the cloth is wet, as was the case so much of the time during the winter of 1936–37, the inside air may be as much as 3 degrees lower.

OVERWINTERING DURING 1938–39.—Experiments in cloth cages, screen-wire cylinder tests, and field scouting were continued during the winter of 1938–39 along

Table 5.—Temperatures of soil in a cloth cage and outside the cage and of manure in a cage, at Uvalde, Tex., December, January, and February 1935–36 and 1936–37.

	1935–36				1936–37			
NATURE OF SITE	Mean (°F.)	Max. (°F.)	Min. (°F.)	Lowest weekly mean (°F.)	Mean (°F.)	Max. (°F.)	Min. (°F.)	Lowest weekly mean (°F.)
Soil in cage	54.8	70	36	46.3	57.5	72	45	54.5
Soil outside of cage	55.8	77	36	47.6	59.8	74	42	57.0
Manure in cage	56.9	80	36	47.1	60.1	76	45	57.2
Air outside of cages	52.2	90	19	40.5	54.3	89	28	47.7

the same lines as in previous years. The flies in the cloth cages did not oviposit, and the colony died without being able to reproduce.

Activity of *Cochliomyia americana* in the field was very much reduced during the winter. Records were obtained of cases in surgical wounds on December 16, January 10 and 13, February 7, and March 28. A considerable number of cases were reported by ranchmen from January 5 to 20. The average daily mean temperature for the three winter months was 54.0° F., and the absolute minimum was 29°.

SUMMARY AND CONCLUSIONS.—*Cochliomyia americana* was able to survive the winter of 1935–36 at Uvalde, Tex., in small numbers with a mean temperature of 52.2° F., mainly because of a warm midwinter period and thousands of wounded hosts, which permitted egg development and oviposition. In the winter of 1936–37 the mean temperature was 54.3°, and the species survived again, apparently because of a midwinter period of activity. Survival of the species occurred during the winter of 1937–38 under a mean temperature of 55.5°. A rather meager survival occurred during the winter of 1938–39 at a mean temperature of 54.0°.

Cochliomyia americana has not exhibited any hibernation tendencies, and progressively declining temperatures from a mean of approximately 55° F. lengthened the developmental period and increased mortality of the immature stages. Apparently a mean, average, daily air temperature of approximately 51° was fatal to most of the immature stages in the soil. All adults were killed in cages at a minimum of 19°, and at a minimum of 22° the flies fell to the ground, although they revived with a rapidly rising temperature, and later oviposited. Oviposition has occurred in the field at 61°, but this was preceded by several days with much higher temperatures.—11-17-44.

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Overwintering of *Cochliomyia americana* and *C. macellaria* at Menard, Texas

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During the winters of the years 1935 to 1939, inclusive, studies were conducted at Menard, Tex., to determine whether the primary screwworm fly, *Cochliomyia americana* C. and P., overwintered in that locality. During the winter of 1936–37, studies were also conducted on the overwintering of the secondary screwworm fly, *C. macellaria* (F.).

From November 14, 1935, to January 7, 1936, 13,500 larvae and pupae of *Cochliomyia americana* were exposed to outdoor conditions. Of this number 3500 larvae were allowed to drop normally from goats and rabbits in a 12-by-12-by-6-foot tobacco-cloth cage on the side of a rocky hill with northern exposure, 2000 larvae were placed in bottomless tubs set in the soil in a river-bottom area and covered with cloth, and the same number were similarly exposed on the side of the hill. During the same period 6000 pupae were buried in the soil at 2-, 4-, and 6-inch depths, 1000 at each depth, in the river-bottom area and on the side of the hill. Each lot of pupae was covered with a cone-type trap to prevent the escape of any flies that might emerge. No emergence occurred in any of the tests of that winter.

During the period October 26, 1936, to January 30, 1937, 45,249 larvae and pupae of *Cochliomyia americana* were exposed in the following way: Four tobacco-cloth cages similar to those used the previous year were constructed, two on the side of a rocky hill, one in a river bottom, and the other on top of a low hill. In all, 24,124 larvae were exposed in these cages. Also,

9025 larvae and pupae were placed under cone-type fly traps, the larvae being placed on top of the soil and allowed to work their way in of their own accord, but the pupae were buried 2 inches in the ground. The carcasses of 11 goats infested in all with an estimated 6600 larvae were covered with screened-top wooden frames. Five hundred larvae were allowed to penetrate each of 11 lots of soil conditioned with one of the following: Manure, fine gravel, caliche, sand, alfalfa hay, oak ashes, debris, pecan leaves, horehound sod, Bermuda grass sod, and mesquite grass sod. Each lot was covered with a screened-top, wooden frame.

At the same time, 12,391 larvae and pupae of *Cochliomyia macellaria* were placed under cone-type fly traps, the pupae being buried 2 inches and the larvae placed on top of the soil.

The only emergence that occurred in these tests was that of 4 females and 2 males from the *Cochliomyia americana* larvae installed in one of the cloth cages on the side of the hill during the period October 26 to November 3. These emerged during the period December 17 to 30, 1936.

In November, 1937, introductions of larvae of *Cochliomyia americana* were made on the following dates: November 2—500 larvae dropped from a live goat; November 12—2000 larvae, nutrition-reared; November 30—500 larvae dropped from a live sheep, all in a 12-by-12-by-6-foot cloth cage. There was no emergence from these lots.

On October 18, 1938, one half of the soil beneath a 12-by-12-by-6-foot cloth cage on a hill was spaded 6 inches deep and the other half left undisturbed. A slatted, bottomless dropping box 34 inches long, 24 inches wide, and 28 inches high was placed in the middle of the cage, half of it on the spaded portion and half on the undisturbed soil. Two bushels of manure, two bushels of dry grass and weeds and eight burlap sacks, to serve as hibernating material for the larvae were distributed around the dropping box. This material was so arranged that approximately half of each of the materials was on the undisturbed portion of the soil and half on the spaded portion.

On October 14 a goat was infested on both shoulders and hips with newly hatched larvae of *Cochliomyia americana*, approximately 100 larvae being placed in each wound. On October 19 the goat was placed in the dropping box, where it remained until all the larvae had left the wounds. On October 28 another goat was infested in the same manner and was placed in the box on November 1, where it remained until all larvae had left the wounds. On November 11 a third goat was infested, placed in the dropping box on November 15, and left there until all the larvae had dropped.

On November 13, a month after the first larvae had been introduced, flies began to emerge. On November 14 there were approximately 300 normal adults in the cage. Water, honey, and hog liver were placed in the cage, and the adults readily consumed the food. On November 21, when there were approximately 100 live adults in the cage, a goat with three wounds which had been infested with larvae of *Cochliomyia americana* was placed in the cage. No oviposition occurred and after that the temperature became too low for fly activity, and on November 25 only two adults were alive. None was alive in the cage on November 26.

On December 7 about 25 adults emerged and were provided for in the same manner as those that had emerged previously. Only one was alive on December 13 and none on December 14.

SUMMARY AND CONCLUSIONS.—Records taken during the winters of 1935–36 to 1938–39, inclusive, on approximately 62,000 exposed larvae and pupae of *Cochliomyia americana* indicate that the temperature in the vicinity of Menard, Tex., will not permit their survival throughout the winter.

No adults emerged from 12,391 larvae and pupae of *Cochliomyia macellaria* exposed during the winter of 1936–37.—11-17-44.

Winter Activity of *Cochliomyia americana* in the Southeastern States

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Results of formal experiments to determine the overwintering activity of *Cochliomyia americana* in the Southeast have not been offered previously, but some notes on the winter activity of this insect were published by Laake *et al.* (1936), in which they refer to records by other workers who reported screwworm cases in Georgia and Florida during January and February 1935. Among these other workers, W. V. King found 17 infestations in northern and central Florida, 15 of which occurred from January 8 to 19, inclusive. In the same paper it is reported that the female could oviposit at a temperature of 65° F. Knipling & Travis (1937) record egg deposition in nature at 63.5° at Valdosta, Ga. Interesting, too, is a statement by Dove & Bishopp (1936) that a temperature of 24° for 3 days in January did not stop activity of the true screwworm fly at Apalachicola, Fla., during warm periods following.

Laake *et al.* (1936) also report data obtained by H. O. Schroeder and C. N. Smith, who found under laboratory conditions that 24° F. for periods not exceeding 7.5 hours was the minimum limit to which eggs could be subjected and still allow at least some eggs to hatch. The minimum to which pupae could be subjected and survive was 13° for periods of less than 5 hours, while 20° F. for periods not exceeding 7 hours was the minimum which adults could survive to lay eggs when warmed later. Laake *et al.* summarized these notes and concluded that killing frosts cause cessation of activity but that in mild winters the temperatures are not low enough to kill the adults.

This paper presents results of studies on the activity of *Cochliomyia americana* during the winter months of 1935–36 through 1938–39. Experiments were conducted in southern Georgia at Valdosta and in northern Florida at Gainesville. Records from other parts of both states are also incorporated, and thanks are due to E. W. Laake and other former members of the Valdosta Screwworm Research Laboratory for their aid.

RESULTS OF CAGE TESTS.—The cage tests, equipment, and methods of procedure used at Valdosta and Gainesville were similar to those used in Texas by Parman and by Lindquist & Barrett.

CAGE TESTS AT VALDOSTA, GA.—During the winter of 1935–36, emergence occurred from larvae that had been placed on the soil on December 31, January 8, and February 8, but installations at other dates failed to produce adults. In field recovery cages, emergence of adults occurred from pupae buried in February but not from those buried earlier. The period from the time larvae were seen leaving carcasses to the time of emergence of adults ranged from 28 to 78 days.

In November 1935 there was a minimum temperature of 28° F., and the temperature dropped below 32° on 4 days. December was exceptionally cold, 17 days having a minimum temperature below 32°. On 12 days in January and 3 in February the minimum was below 32°.

Soil-temperature records are incomplete but those available indicate that the average maximum soil temperature at the 2-inch depth was about 2 Fahrenheit degrees higher than the mean air maximum, whereas the mean soil minimum temperature was 6 degrees higher than the mean air minimum. All pupae buried in these tests were put at the 2-inch depth.

During the winter of 1936–37, flies emerged from every lot of pupae buried in field recovery cages from December 3 to February 23. A graph showing the emergence from pupae during 1935–36 and 1936–37 is presented in figure 1. Installations of larvae from December 2 to February 23 likewise resulted in emergence in every case. In two out of four cloth cages stocked with larvae in October, breeding was continuous throughout the winter in the wounded animals supplied as needed. The preoviposition period ranged from 6 to 30 days, but the developmental period in the wound was about the same as in summer. The period in the soil, from the

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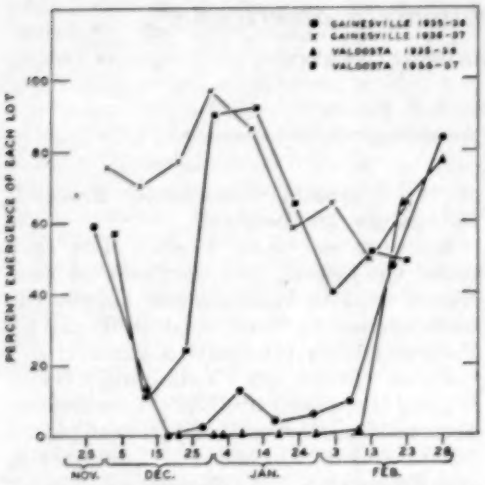

FIG. 1.—Comparison of emergence from pupae of *Cochliomyia americana* buried under 2 inches of soil, Valdosta, Ga., and Gainesville, Fla., 1935–36 and 1936–37.

dropping of mature larvae to the emergence of adults, ranged from 18 to 54 days. The maximum life of the adult in this series was 61 days. There was some slight, but not conclusive, evidence that well-rotted manure protected larvae and pupae from the cold, although the percentage of emergence from manure was not consistently greater than that from other soil in which development took place. In some cases pupal development in manure was shorter than in any other soil type (Fig. 2).

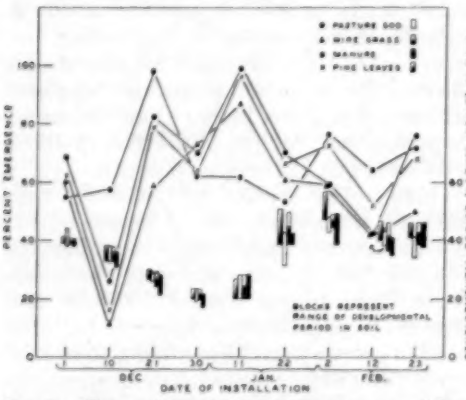

FIG. 2.—Comparison of per cent emergence and days to develop of immature stages of *Cochliomyia americana* under different soil environments. Valdosta, 1936–37.

Temperatures in the winter of 1936–37 dropped below 32° F. on 6 days in November, 2 in December, 7 in February, and 2 in March.

In the winter of 1937–38, four cage tests in which infested carcasses were deposited on different types of soil on November 10, December 20, January 4, and February 2 resulted in emergence of flies in all cases. Beginning the last week in October, four cultures of larvae were begun on animals in cloth cages, but none of them carried the species through the winter.

A high emergence was recorded from larvae dropped on manure, when low temperature was the probable cause of low emergence from other types of soil. The

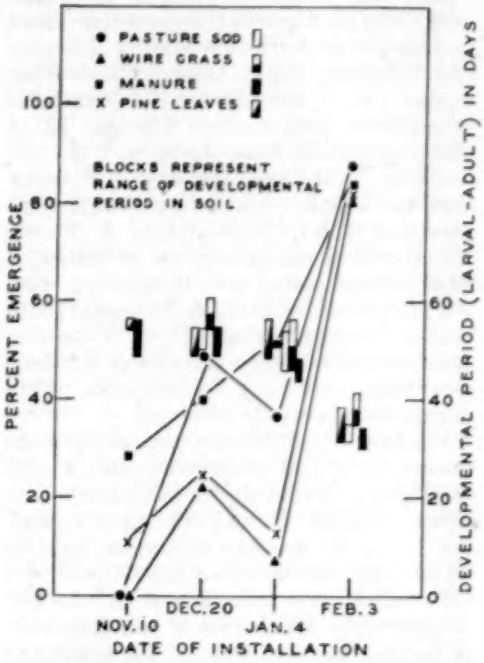

FIG. 3.—Comparison of per cent emergence and days to develop of immature stages of *Cochliomyia americana* under different soil environments. Valdosta, 1937–38.

length of the period from installation of the larvae to adult emergence was also shorter than in the case of larvae placed on other types of soil (Fig. 3).

The temperatures dropped to 34° F., or below, on 4 days in November, and in December the minimum was 33°, or lower, on 12 days. In January the minimum was 31°, or lower, on 6 days.

During the winter of 1938–39, carcasses infested with screwworms were deposited on soil on November 11, December 21, January 6, 10, and 17, February 6, and March 1 and 7. Adults emerged in each case excepting that of the installation of

January 10. The average emergence from cages containing manure was no greater than that from the others excepting during extremely cold weather. The developmental period in manure was shorter in every series of tests (Fig. 4). Two cultures of larvae were begun in cloth cages in October, but neither survived the winter. The second generation of flies of one of these had emerged on February 14 but died out on February 21. Another culture begun with flies that had emerged from other outdoor experiments was carried through the remainder of the winter without difficulty.

In November the temperature dropped to 30° F., or lower, on 5 days. In December the minimum was 32°, or lower, on 8 days. In January the minimum was below 32° on 6 days and in February on 2 days.

TESTS AT GAINESVILLE, FLA.—During the winter of 1935–36 emergence of adults occurred from all lots of buried pupae with the exception of the lot buried on December 18. In the series of installations made by depositing infested carcasses on the soil, emergence of flies took place in all cases. From the installations of December 12 and January 17, however, only one fly emerged in each case, and installations on November 27 and December 18 produced only two flies each. All others ran considerably higher in production.

In 1936–37 a high degree of emergence was recorded for all lots of buried pupae, and equally positive results were obtained from installations of larvae on pasture sod. One culture in an outdoor screened cage bred continuously throughout the winter. In this cage adult flies lived a maximum of 49 days. The preoviposition period ranged from 12 days in April to 15 to 22 days in December and January. The developmental period in the wound was from 5 to 7 days, and the period spent in soil was 19 days in January, 32 in November and December, and 33 in March.

In 1937–38 a culture, begun in a cloth cage on November 1, bred throughout the winter without difficulty. The developmental period in the soil ranged from 17 to 37 days, the preoviposition period from 11 to 27 days, and the maximum length of life in the adult stage from 28 days in February and March to 49 days in December and January. The following winter, 1938–39, a culture was likewise maintained throughout the season without difficulty.

NATURAL WINTER ACTIVITY: GEORGIA.—In the fall of 1935, screwworm flies were active in egg deposition until December 10. Between January 16 and 20, 1936, four egg masses were found in wounds of animals. During the same period two other cases were reported on farms in Lowndes County, Ga. No others were encountered until April 11.

In the fall of 1936, the last fly to be caught by trapping was found in the trap collection for the week ended November 19. A case of screwworm infestation was found on November 10, and on January 23, 1937, screwworms were found in the cut horn of a steer. Screwworm cases were found in Brooks County, Ga., on January 20, 1937.

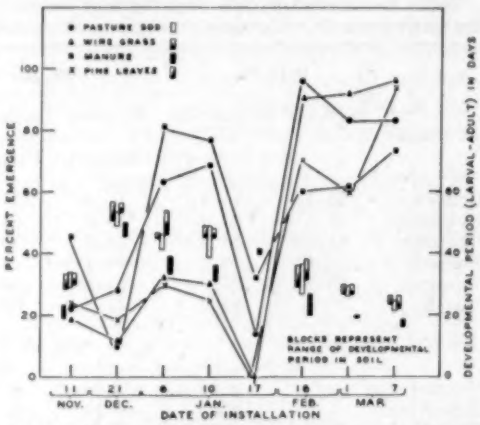

FIG. 4.—Comparison of per cent emergence and days to develop of immature stages of *Cochliomyia americana* under different soil environments. Valdosta, 1938–39.

The last fly to be caught in a trap in the fall of 1937 was found in the collection for the week ended November 8. The last observed infestation was found November 10. During the following winter one case was reported from Quitman, Ga., on January 21, 1938, and another about the middle of February, but no specimens were collected from either. The first positively identified case in 1938 was found on June 16.

Screwworm flies were exceptionally active during the fall of 1938 and the following winter. They were found in trap collections in October, November, and December, and in that of the collection for the week ended January 9, 1939. None were caught during February and only one during March, but beginning with the

week of April 17 *Cochliomyia americana* was caught regularly in the fly trap. Natural infestations were recorded throughout October and November, but only one in December, none in January, and one in February. Activity recommenced in March, and the number of screwworm cases increased rapidly. One case was reported from Tifton, Ga., during the first week in April.

Northern Florida.—In 1935–36 at Newberry, Fla., a few miles south of Gainesville, the last appearance of *Cochliomyia americana* in a trap occurred during the week of December 2–9.

Gainesville, Fla., may become low enough to retard development but during the winters of 1935 to 1939, inclusive, breeding was more or less continuous.

The northern limit of winter survival of *Cochliomyia americana* passes probably near Valdosta, Ga. During the 4 years of experiments *C. americana* passed the winter at Valdosta in outdoor screened cages only during 1936–37 and 1938–39. If any one winter month can be considered crucial, that month would be January. A glance at the mean air temperatures (Table 1) shows that in those 2 years when *C. americana* did not survive, the mean tem-

Table 1.—Meteorological data for four seasons during which investigations were being made on the screwworm (*Cochliomyia americana*) at Valdosta, Ga., and Gainesville, Fla.

	1935–36		1936–37		1937–38		1938–39	
	Valdosta	Gainesville	Valdosta	Gainesville	Valdosta	Gainesville	Valdosta	Gainesville
	Mean Air Temperature (°F.)							
October	69.4	74.4	71.9	74.7	67.3	70.0	65.3	68.6
November	59.5	65.5	56.9	61.6	56.6	60.5	61.7	65.9
December	45.7	50.2	54.2	59.5	51.0	55.8	51.5	56.0
January	51.5	56.9	64.4	68.8	52.5	56.6	56.3	59.1
February	50.4	57.0	55.3	58.7	60.1	62.8	62.1	65.5
March	59.4	64.0	57.2	61.2	65.9	69.5	64.1	67.0
	Rainfall (Inches)							
October	—	0.40	5.22	8.13	2.17	4.40	3.20	9.19
November	—	0.67	0.10	0.10	3.73	3.88	1.05	0.74
December	1.64	1.97	5.43	2.63	1.37	1.76	2.44	0.53
January	5.45	3.97	1.04	3.32	1.37	1.90	3.18	1.84
February	4.97	7.88	3.85	4.60	0.87	2.24	6.92	5.70
March	2.15	2.78	5.72	3.03	1.95	1.38	1.60	1.01

In 1936–37 the Screwworm Control Division of the Bureau of Entomology and Plant Quarantine reported screwworm cases on January 5 from Lake City, Fla., about half way between Valdosta, Ga., and Gainesville, Fla.

In 1937–38, the same division reported 69 screwworm cases from Madison County in November and 19 from Levy County in December. For the week ended January 8, two cases were reported, and for the week ended January 22, five cases were reported from Levy County.

In 1938–39, numerous cases were reported throughout the winter in the counties of Madison, Jefferson, Taylor, and Lafayette.

MISCELLANEOUS OBSERVATIONS.—*Cochliomyia americana* has no true hibernation period. The air temperatures at

perature for January was below 56° F.; whereas during the 2 years when it did survive the mean temperature for January was above 56°. No such relationship is evident between survival and the temperatures in any other winter month. A review of total rainfall shows no consistent relationship between rainfall and survival.

Although *Cochliomyia americana* may not always survive the winter at Valdosta, it can remain inactive, but alive, for comparatively long periods. For instance, while normally the developmental period during summer in the soil lasts from 7 to 9 days, during the winter it may last as long as 75 to 78 days, and periods of 30, 40, or 50 days are frequent. Even at Gainesville the developmental period in the soil was prolonged in one case to 63 days.

Formal studies regarding survival in re-

lation to controlled temperatures were not conducted, but some interesting observations in relation to this subject were made. In 1937–38, immature stages developed and adults emerged even after 6 consecutive nights during which the daily minimum was below 32° F., and larvae or pupae at the depth normally occupied withstood 16 nights when the minimum soil temperature fell below 32° F., 8 of these being consecutive nights.

The adults can also withstand short periods with temperatures below freezing but may not be able to withstand long periods of comparatively mild or moderately cool weather, as when the daily maximum remains consistently below 70° F. On the other had, adults, although usually inactive in outdoor cages even at temperatures between 60° and 70°, were observed to emerge and spread and harden their wings normally on a day when the air temperature did not rise above 54°. During a winter period when records of 32° or below were made on 14 days and records of maximum temperatures below 60° were made on 21 days, the maximum longevity of adults under observation was 64 days. These flies deposited viable eggs.

SUMMARY.—Experiments to determine the nature and extent of winter activity of *Cochliomyia americana* at Valdosta, Ga., and Gainesville, Fla., were carried on during the winters of 1935–36, 1936–37, 1937–38, and 1938–39.

All experiments at Gainesville indicated that *Cochliomyia americana* could breed through the winter in that locality.

Valdosta, on the other hand, was indicated as being nearer the northern limit of overwintering. During the 4 years in which breeding experiments in outdoor cages were conducted, *Cochliomyia americana* survived only through the winters of 1936–37 and 1938–39. A few natural cases of infestation were observed, however, during a warm period in January 1936.

Soil environments are somewhat significant in relation to survival of the immature stages during cold weather. Well-rotted manure apparently provided some protection, since during cold periods a greater percentage of emergence was usually obtained from larvae planted in manure, and the development was more rapid than in other types of soil.

Cochliomyia americana has no true hibernation period. The period of development of the immature stages in the soil under normal summer conditions is from 7 to 9 days, but under winter conditions at Valdosta it was prolonged in one case to 78 days. Even at Gainesville this period may be prolonged to 63 days.

Adults of this species have been kept alive for a period of 64 days.—11-17-44.

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PARKER T. BARNES

Parker T. Barnes, formerly on the staff of the Pennsylvania Bureau of Plant Industry, died at Hummelstown, Pennsylvania, on May 31, 1944. He was born at Marshfield, Massachusetts, on December 29, 1874.

He studied at the Bussey Institution of Harvard University, worked and studied under Jackson Dawson at the Arnold Arboretum after which he was located at the Geneva Experiment Station for several years. During the late nineties he was cataloguer and photographer at the Shaw Botanic Gardens, St. Louis, Missouri. Early in this century he assisted in cataloging the flora of the Philippine Islands. Following his return from the Islands he served as associate editor of *Country Life* after which he held a similar position with *Suburban Life*. He joined the Horticultural Survey of the State of Pennsylvania about 1912 while it was still under the direction of H. A. Surface The tour to duty with the state was followed by a few years as assistant to the head of the insecticide division of the Sun Oil Company. At the time of his death he was operating his farm near Hummelstown.

He is survived by his wife Emma Miller Barnes.

Overwintering and Dispersion of *Cochliomyia americana* in Arizona

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The data presented in this paper are the results of studies made on the screwworm, *Cochliomyia americana* C. & P., in southern Arizona during the winters of 1936–37 and 1937–38. Overwintering areas, conditions under which the adults were active, and dispersion of the flies were determined by the use of fly traps baited with liver, and by scouting for screwworm cases. Cage tests on the overwintering of the immature stages were made at Tempe, Ariz. The work was done under the direction of D. C. Parman.

Cochliomyia americana did not survive the cold winter of 1936–37 in Arizona. In years when the temperatures are normal or above, *C. americana* survives not only in the Salt and Gila River Valleys but also in the warmer valleys to the southeast. A fly-free period, therefore, cannot always be assured. Since this is true, it is important to know the temperatures at which the species is killed or rendered inactive. A knowledge of the areas in which the primary screwworm fly can overwinter is essential in understanding or determining natural dispersion, seasonal adult populations, conditions contributing to large fly populations, and the time infestations are likely to appear in adjoining areas.

Climatic conditions are important factors influencing populations of *Cochliomyia americana*. During the winter months the numbers of the flies are reduced to a minimum, and the area over which the species occurs is curtailed. The spring infestations of *C. americana* depend, to a large extent, on the weather conditions of the preceding winter.

Cage Studies, Winter of 1936–37.—By means of an extended pupal period the screwworm can survive a certain amount of winter temperatures. Cage tests were made at Tempe to determine the conditions under which the species could successfully carry through the winter in the immature stages. Three experiments were carried out as follows: (1) A series of tests in which mature larvae were permitted to pupate in screen cages under varied conditions, (2) a series in which larvae and pupae were installed at different periods in 10-inch screen cylinders set on the soil surface, (3) a series in which pupae were buried at various depths in the soil under 10-inch screen cylinders. In three of the cages used in the last series of tests, mature larvae were also permitted to enter the soil.

Pupation Under Various Conditions.—In the first of these tests, screen cages, 2-by-2-by-2 feet, were placed over (a) cultivated soil, (b) grass sod, (c) manure 12 inches deep, and (d) leafmold 4 to 6 inches in depth. Larvae collected from wounds were placed in these cages on November 14, 18, 19, 22, 24, and 26, and December 16. Owing to the difficulty of obtaining mature larvae, only 75 were used in each cage. Soil temperatures in each of the cages were taken daily, at 9 a.m. and 2 p.m., during the progress of the experiment.

Cultivated soil was found to be the most favorable for the survival of the immature stages. Emergence in this soil began on December 22, and continued until January 15, and 20 per cent of the larvae reached the adult stage and emerged. The mean temperature of the soil from December 20 to January 16 was 51.8° F. The mean temperature of the cultivated soil during January was 45.6°.

Of the larvae that pupated in the manure, 17 per cent emerged between December 11 and 23. These flies were evidently from the larvae placed in the cages in November. The mean temperature of the manure from December 12 to 26 was 60.9° F. and during January it was 44.2°.

Only one fly emerged in the grass-sod cage, and two emerged in the leafmold cage. In these environments the soil tended to be shaded and a lower maximum temperature resulted. The mean temperature of the leafmold during January was 44.4° F. and of the grass sod 44.1°.

Survival of Larvae and Pupae, 1936–37.—Between December 4, 1936, and January 13, 1937, 362 larvae and 250

pupae were introduced at different intervals into cylindrical screen-wire cages placed on the surface of the soil. No emergence occurred from this material. As these cages adjoined the screen-wire cages used for the first series of tests, the soil temperatures were the same as in the cages over cultivated soil.

Four cages containing 300 larvae and 200 pupae were installed on February 2, 9, and 10. From 20 to 96 per cent of this material completed development. The period in the soil was from 27 to 41 days. The mean soil temperature during February was 55.6° F.

A 10-inch screen-cylinder cage was also used in tests with larvae and with pupae buried at different depths. Each series was installed at a different time and each consisted of the following: (a) Fifty larvae on range soil, (b) 50 larvae on cultivated soil, (c) 50 larvae on 6 inches of manure, (d) 50 pupae buried 6 inches deep in 12 inches of manure, (e) 50 pupae 2 inches deep in soil, (f) 50 pupae 6 inches deep in soil, (g) 50 pupae 10 inches deep in soil, and (h) 50 pupae 20 inches deep in soil.

The first series of insects was installed November 10 and 11. The flies emerged from those put in as larvae in from 21 to 49 days, and in from 14 to 32 days from the pupae. The pupae buried 20 inches deep were the first to develop to flies. In two of the cages begun with larvae, 100 per cent emerged; and from 44 to 80 per cent of the buried pupae completed development.

The second series was installed January 1 to 4. None of the 150 larvae or 250 pupae completed development, owing to the abnormally cold weather during January.

A third series was installed January 30 to February 1. Emergence occurred in all except the 6-inch, 10-inch, and 20-inch burial cages. The length of the developmental period of the immature stages in the soil was from 39 to 46 days. In the cultivated soil 48 per cent of the flies emerged. The larvae and pupae for this series were obtained from laboratory rearings with a rabbit as a host.

It is evident from these tests that mortality of the immature stages was due to the abnormally low temperature during January. The mean air temperature at Tempe during January was 41.6° F., which was 8.4 degrees below the normal.

FIELD ACTIVITY, WINTER OF 1936–37.—Standard, liver-baited traps were operated in the Salt River Valley, Yuma Valley, and along the escarpment from Phoenix to Prescott. Peak populations were shown by catches in the status traps of 104 *Cochliomyia americana* females at Tempe for the 15-day period ending October 15, 136 at Canon for the 12-day period ending November 1, and 330 at Wickenburg for the 14-day period ending October 25.

As the weather became cooler, the population of *Cochliomyia americana* decreased rapidly. On December 31, two females were removed from the trap at Tempe, and 11 females were taken at Canon for the period ended January 1, 1937. These were the last specimens taken in these traps until the following summer.

Screwworm cases caused by *Cochliomyia americana* continued to be found in 1936 until December 25. Although scouting was rather thorough during January and February, no cases were found which were caused by *C. americana*.

The adult population of the fly in Arizona during the fall of 1936 was relatively high; yet the low winter temperatures, which were abnormal, resulted in the complete eradication of *Cochliomyia americana* in Arizona. These field studies verified the cage tests, where it was found that the low January temperatures were fatal to the immature stages.

DISPERSION AND MIGRATION.—The eradication of *Cochliomyia americana* from Arizona by the cold winter of 1936–37 afforded an opportunity to study the source of reinfestation and the migration of the screwworm fly to that state during the following spring. The ranchers on the southern Arizona ranges report that under normal conditions screwworm infestations of livestock begin in March and April. In years when the winters were open, screwworm cases were reported during the winter months. Weather records indicate that in normal years *C. americana* is killed out, except in the Salt River and Gila River valleys and adjoining warm areas. The physiography of the country would indicate that reinfestation of the range sections of the southeastern part of the state was partly from a source other than these warm valleys, in which the winter temperatures are usually high, as they have a lower elevation than the adjoining

range country to the south and southeast.

The topographical and ecological conditions in southern Arizona must be considered in a study of screwworm reinfestation and dispersion. The section from Gila Bend to Yuma is entirely desert, with a low animal population, and is unfavorable for blowflies. If reinfestation is to occur when *Cochliomyia* is killed out in these valleys, migration must take place through the range sections of higher elevations to the south. The range section in the southern and southeastern part of the state is broken up into valleys which run north and south and are separated by more or less well defined mountain ranges. The more important rivers flow north to the Gila River, whereas the drainage from adjoining areas flows south directly into Mexico.

Table 1.—Dispersion of *Cochliomyia americana* in Arizona during 1937.

Locality	Date	Material Collected
Papago Indian Reservation, Pima County	May 11	Adult
Stark, Cochise County	May 16	Larvae
Sasabe, Pima County	May 21	Larvae
Sells, Pima County	May 25	Adults
Benson, Cochise County	May 25	Larvae
Nogales, Santa Cruz County	May 26	Adults
San Bernardino, Cochise County	June 1	Larvae
Tucson, Pima County	June 10	Adults
Gila Bend, Maricopa County	June 24	Larvae
Wickenburg, Maricopa County	July 2	Adults
Tempe, Maricopa County	Aug. 16	Adults

In March 1937, traps were placed along the international border at Nogales and Sasabe, and in adjacent readily accessible areas from Sells to Yuma. Scouting for screwworm cases was continued in all sections of the state to determine the date of first appearance of *Cochliomyia americana*, and to ascertain if any warm areas where the fly might possibly have overwintered had escaped notice in the intensive winter scouting.

The first recorded catch of *Cochliomyia americana* in the spring of 1937 was in a trap located on the Papago Indian Reservation, between Sells and Ajo, on May 11. The traps proved very effective in showing the presence of the flies, but since they were serviced only every 2 weeks, the exact date when the flies entered the trap was unknown. The date recorded is that when the trap was changed. This record strongly indicates that adults had migrated by flight from Mexico, since there is apparently no transportation of livestock from Mexico through this area or other means by which the flies could have been brought in.

At approximately the same time, separate reinfestations occurred along the entire southern border, as shown in table 1. Records for Cochise County are from the data of T. J. Schmitt of the Screwworm Control Division, Bureau of Entomology and Plant Quarantine, who cooperated in the scouting work.

Because of cool weather during March and April with resulting late reinfestations, wide dispersion did not occur prior to the hot, dry months, which also checked activities to some extent. A deficiency of rainfall occurred in most sections of the state during 1937. Dispersion was erratic and slow. A large population did not build up except in Pima, Santa Cruz, and Cochise counties, where early reinfestation and moisture conditions were favorable. Infestations by *Cochliomyia americana* over the state as a whole were below normal.

CAGE STUDIES, WINTER OF 1937–38.—As in 1936, cage tests were conducted at Tempe, and scoutings for screwworm cases were made during the winter months. In addition to the status traps used the previous year, survey traps were operated in the southeastern part of the state where, owing to an abnormally warm winter, cases were reported and adults were taken throughout the winter.

Tests on the various types of soil were conducted as during the previous winter. On November 8, 1937, 100 larvae were placed on the soil in each of four cages. By accident, the cages were flooded by irrigation water to a depth of 2 to 4 inches on November 13. Additional installations were delayed until December 14 so that the effects of the irrigation water on the immature stages could be determined. Table 2 gives the results from this unintended test. From December 14 to 24, inclusive, the four cages were restocked with 200 larvae each. The emergences from these larvae are also recorded in table 2. The mean soil temperatures covering this second installation are for the period December 19, 1937, to February 27, 1938, inclusive.

These data indicate that the mean minimum temperature which the immature stages can withstand in the soil is near 52° F., and would of course vary, depending on other conditions involved. The maximum length (70 days) of the immature stage in the soil shows the ability of the species to adapt itself to short periods of unfavorable weather.

Following the procedure of the previous winter, three installations were made in the series of tests in which larvae were introduced and pupae were buried. One hundred and fifty larvae and 250 pupae were used in each series. The pertinent data for these series are given in concise form in table 3. The mean soil temperature from November 14 to December 12 was 57.0°; from December 20, 1937, to February 20, 1938, 53.5°; and 56.5° F. for the period January 23 to March 4, for the cultivated soil. These data show that temperatures remained high enough to permit suvival throughout the winter. Because of lower temperatures, larvae and pupae in the second series required a longer period for development. The mean air temperature for the second series was 52.3°, and for the third, 53.9°.

ADULT ACTIVITY, WINTER OF 1937–38.—Except for short periods, adults of *Cochliomyia americana* were active throughout the winter in the warm valleys of southern Arizona. Adult flies were present in southeastern Arizona until January 1, as shown by traps located at Sonoita, Fairbanks, and Douglas. There were adults at Nogales throughout the winter. Trapping records show *C. americana* taken during the winter months at Tempe, Wickenburg, Canon (P.O. Bumble Bee), Gila Bend, Somerton, and Yuma. These records indicate survival over a rather widespread area.

The mean monthly air temperatures at various representative points in the overwintering areas are given in table 4. Monthly means of 52.6°, 51.6°, and 52.6° F. for December, January, and February, respectively, did not prevent survival of *Cochliomyia americana* at Nogales.

Infestations of *Cochliomyia americana* in wounds were numerous in the Salt River Valley through November and December, 1937, and the first 2 weeks of January of 1938. Temperatures during December and January were above normal. Collections of larvae from wounds were made on December 30, 1937, at Mesa and on January 14, 1938, at Phoenix. Infestations caused by *C. americana* were not found by scouting after January 14. Adults were present in nature, however, as shown by trapping records and emergence in the overwintering cages. It is indicated that the temperatures were not high enough to permit the female flies to mature their eggs. The minimum temperature for January was 28° F. (January 11). Probably the continued low mean temperatures were responsible for checking infestations in the field, since a minimum of 28° in the Yuma Valley on January 30 did not check infestations in that area.

In the Yuma Valley an outbreak occurred during November, December, and February, and continued through the spring. Collections from wounds were made on February 17 at Somerton in which third-instar *Cochliomyia americana*

Table 2.—Emergence of adults of *Cochliomyia americana* from larvae placed in different environments and flooded once by irrigation water, and installations repeated but not flooded. Winter of 1937–38, Tempe, Arizona.

Cage Site	Cages Flooded			Cages not Flooded		
	Mean temp. of medium (°F.)	Number[1] emerged	Maximum length of immature stage in medium (days)	Mean temp. of medium (°F.)	Number[2] emerged	Maximum length of immature stage in medium (days)
Cultivated soil	56.0	30	51	53.9	145	60
Grass sod	53.1	1	60	51.3	0	—
Leafmold	54.8	2	51	52.1	18	60
Manure	57.8	48	40	53.4	62	70

[1] 100 larvae had been placed in each environment.
[2] 200 larvae had been placed in each environment.

Table 3.—Emergence of *Cochliomyia americana* from larvae placed on soil and pupae buried in it at Tempe, Ariz., winter of 1937–38.[1]

Cage Condition	Date Installed	Number Emerged	Date Emergence Began	Length of Immature Stages in Soil (days)
Series I	*1937*		*1937*	
Larvae:				
Range soil	Nov. 14	18	Dec. 6	22–46
Cultivated soil	Nov. 14	44	Dec. 16	32–46
6 in. manure	Nov. 14	10	Dec. 13	29–44
Pupae:				
6 in. deep in 12 in. of manure	Nov. 14	18	Dec. 3	19–24
2 in. deep in soil	Nov. 14	28	Dec. 7	23–38
6 in. deep in soil	Nov. 14	19	Dec. 6	22–26
10 in. deep in soil	Nov. 14	14	Dec. 4	20–24
20 in. deep in soil	Nov. 14	29	Nov. 30	16–20
Series II	*1937*		*1938*	
Larvae:				
Range soil	Dec. 18	23	Jan. 22	35–65
Cultivated soil	Dec. 18	19	Feb. 10	54–65
6 in. manure	Dec. 18	11	Jan. 28	41–54
Pupae:				
6 in. deep in 12 in. of manure	Dec. 18	6	Jan. 30	43–51
2 in. deep in soil	Dec. 18	20	Feb. 10	54–61
6 in. deep in soil	Dec. 18	No emergence		—
10 in. deep in soil	Dec. 19	No emergence		—
20 in. deep in soil	Dec. 19	6	Jan. 23	35–38
Series III	*1938*		*1938*	
Larvae:				
Range soil	Jan. 23	11	March 8	44–51
Cultivated soil	Jan. 23	33	March 1	37–51
6 in. manure	Jan. 23	35	March 1	37–46
Pupae:				
6 in. deep in 12 in. of manure	Jan. 25	40	March 1	35
2 in. deep in soil	Jan. 25	32	March 2	36–43
6 in. deep in soil	Jan. 25	9	March 4	38–42
10 in. deep in soil	Jan. 25	7	March 4	38–42
20 in. deep in soil	Jan. 25	7	March 1	35–41

[1] 50 of each stage were used in each separate test.

Table 4.—A comparison of the mean monthly temperatures during the winters, 1936–37 and 1937–38 at representative points in southern Arizona. (From records of the U. S. Weather Bureau.)

Weather Station	Year	November (°F.)	December (°F.)	January (°F.)	February (°F.)	March (°F.)
Nogales	1936–37	56.2	49.3	40.5	52.4	54.0
	1937–38	59.0	52.6	51.6	52.6	56.5
Tucson	1936–37	59.9	50.8	41.2	52.8	56.0
	1937–38	59.4	54.3	52.4	54.2	57.6
Tempe	1936–37	59.1	51.0	41.6	52.8	57.8
	1937–38	57.5	54.1	52.7	54.6	57.4
Phoenix	1936–37	61.8	53.2	43.2	54.7	59.9
	1937–38	62.3	56.9	55.0	56.4	59.4
Yuma	1936–37	63.5	56.0	44.9	57.8	63.3
	1937–38	64.1	60.3	58.4	58.2	62.2
Yuma Valley	1936–37	60.1	52.4	42.8	54.5	59.4
	1937–38	60.3	57.1	54.2	54.4	57.0

were taken, showing that continued infestations may occur at monthly means of 54.2° and 54.4° F. Reports of stockmen in this area indicate that there was a high population at the beginning of the winter period.

SUMMARY AND CONCLUSIONS.—*Cochliomyia americana* did not survive the abnormally cold winter of 1936–37 in Arizona. A monthly mean of 41.6° was fatal to all stages during January at Tempe. Reinfestations of the Arizona ranges apparently were caused by adults that migrated from Mexico. Such reinfestations depend on favorable weather conditions in Arizona. The lateness of the reinfestations and drought conditions in this season prevented wide distribution and the building up of an appreciable fly population prior to the summer rainy season.

Cochliomyia americana survived the winter of 1937–38 in the warm valleys of southern Arizona. Continued breeding occurred throughout the major part of the winter. In grass sod at Tempe a mean soil temperature of 51.3° F. prevented development of immature stages in the soil. In leafmold the pupae developed with a mean temperature of 52.1°. The maximum period for development of immature stages in the soil was 70 days.—11-17-44.

Studies on the Mexican Fruitfly Known as *Anastrepha fraterculus*

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Anastrepha fraterculus (Wied.) was described from Brazil and in South America is a pest of outstanding importance. Alan Stone (1942), in his treatment of the genus *Anastrepha*, considers *A. fraterculus* to be a single species ranging from the Rio Grande Valley in Texas to Argentina and Chile in South America. A. C. Baker (1944), however, considers the form occurring in Mexico to be distinct from typical *A. fraterculus* (Wied.), and to indicate this distinction the Division of Fruitfly Investigations refers to the Mexican form as Mexican *Anastrepha fraterculus*. This is the sense in which *Anastrepha fraterculus* is used in this paper.

The Mexican form appears to be rare in Morelos, the guavas there being attacked by *Anastrepha striata* Schiner. In the northern part of the Republic, however, it attacks guavas and peaches. The discovery in July 1941 of heavy infestation in rose apples (*Eugenia jambos* L.) in the vicinity of Coatepec, Veracruz, made possible the rearing of large numbers of this form at the Mexican laboratory and the inauguration of biological studies, the results of some of which are here reported.

Previously, infested rose apples had been obtained by the laboratory at Cordoba, Veracruz, but these were infested almost altogether by Mexican *Anastrepha mombinpraeoptans*,[2] and yielded only a very few examples of Mexican *A. fraterculus*.

The distinctions between *Anastrepha fraterculus* of South America and Mexican *A. fraterculus* as given by Baker (1944) are aside from certain morphological characters, the fact that host responses appear to be different. In Mexico citrus appears not to be attacked whereas in South America citrus is a common host. Peach and guava are attacked in both regions although no information could be gathered about the scattered peaches in Coatepec. Tropical almond, *Terminalia catappa*, is attacked in Mexico but has not been reported as a host in South America. These differences in host relations and the associated minor morphological differences led Baker (1944) to hold the Mexican form tentatively distinct from the South American one pending careful biological work on the two forms. The present studies represent a beginning along that line as far as the Mexican form is concerned.

So far the evidence seems to support the idea that the two forms of *Anastrepha fraterculus* are distinct. Fruit-infestation studies in the laboratory gave the follow-

[1] Grateful acknowledgment is made to Donald F. Starr for his assistance on the statistical methods used here.

[2] The form attacking ciruela in abundance in Morelos, etc., is considered by A. C. Baker (1944) to be distinct from *Anastrepha mombinpraeoptans* Sein of Puerto Rico. For this reason the Division of Fruitfly Investigations refers to the Mexican form as Mexican *A. mombinpraeoptans*.

ing results: Peach, jobo, pear, guava, loquat, and plums were positive; grapes seemed to be preferred for oviposition, but no flies could be reared through; coffee berries, also, were desirable oviposition material, but no development was seen; orange, mango, *Mangifera indica* L., and cherimoya, *Annona cherimola* Mill., were negative. So far as this work has gone, therefore, experimental results with hosts agree more nearly with the situation found in nature in Mexico than with that found in nature in South America. Whether response regressions of the two forms will differ will have to wait on comparable data on the South American form and complete data on both. The question,

Table 1.—Data on eggs of Mexican *Anastrepha fraterculus* at 25° C., to illustrate method of computation.

Observation, Hours	Hatching Range		Hatch	Per Cent Hatch
	Hours	Log		
71[1]	—	—	0	0
72.5	1.5	0.176	4	5.2
73.25	2.25	.352	3	9.1
74.38	3.38	.529	8	19.5
76.07	5.07	.705	10	32.5
78.61	7.61	.881	18	55.8
82.42	11.42	1.06	15	75.3
88.13	17.13	1.23	8	85.7
96.7	25.7	1.41	7	94.8
109.6	38.6	1.59	2	97.4
136.7	65.7	1.82	2	100

[1] Represents the incubation period.

however, is of real economic importance. *Anastrepha fraterculus* in South America is an important pest of several crops. If the identical species is now occurring in large numbers in Mexico and migrating extensively into the United States, the matter is one for consideration. If, however, the form in Mexico is native there, primarily associated with guavas in the northern regions, where it does not attack citrus and only occasionally attacks peaches, the problem takes on a different complexion. Mortality regressions by fruit treatment with the vapor-heat process are being obtained by W. E. Stone, J. W. Balock, and J. G. Shaw on the Mexican form and these will serve as added evidence when such data on the South American form become available.

FOOD AND OVIPOSITION-MATERIAL REQUIREMENTS.—Oviposition has been poor with the small numbers of this species available heretofore, which were fed sliced orange, sugar, and water. Because difficulties in obtaining a sufficient number of eggs from several other species of fruitflies were solved by diets[1] (Allman 1939, Fluke & Allen 1931), tests were run on this species to determine which food would give the best results. Apparently sugar and water were sufficient to keep the flies alive but there was nothing to aid in egg development, whereas the addition of a protein (brewers' yeast or casein) to the normal diet of orange, sugar, and water increases egg production. Likewise the selection of a suitable oviposition material is of utmost importance. Slight egg laying was recorded from jobo, peach, and plum, all hosts of the fly. (Roseapple could not be obtained at the time and so was not used.) However, prolific oviposition took place in grape even though this fruit is not a host of this fly. With grapes it was necessary to use the large, dark, sweet table grape, for otherwise the eggs failed to hatch, even if removed within an hour after oviposition.

EGGS.—At a constant temperature of 25° C., the first mating was seen on the morning of the sixteenth day. Eggs were first laid on the twentieth day. Since this was with three females, it is possible that with a larger population the time might be shortened. The eggs, which are simple and not stalked as are those of the closely related Mexican *Anastrepha mombinpraeoptans*, are laid singly or in groups up to eight but usually are found alone or in groups of two or three. Oviposition has been observed at 19° C., but observations show that the best oviposition was obtained at temperatures of from 35° to 40° C. although this temperature cannot be held long because of the deleterious effect on the flies. When eggs for incubation studies were being obtained, however, the temperature was between 22° and 25° C. over the 3-hour oviposition period.

Eggs were obtained by using the fruit-skin method[2] in which flies are induced to oviposit in hollowed-out sections of fruit and the eggs then removed; in this case grape-skin sections were used. Eggs were placed on blackened filter paper, moistened with a dilute solution of cupric chloride (Darby and Kapp 1933), and put

[1] Marlowe, R. H. Unpublished data on the melon fly, *Dacus cucurbitae*.

[2] Keck, C. B. Technique used in biological research with the Mediterranean fruit fly. Fla. Med. Fruit Fly Res. Rpt. 72 to U. S. Bur. Ent. and Plant Quar., 22 pp. May 5, 1930. [Unpublished.]

into stender dishes to be incubated at the desired temperatures. Eggs were studied at 15°, 17.5°, 20°, 22.5°, 25°, 27.5°, 30°, and 32.5° C.

Since a relatively large proportion of the eggs hatch during the first part of the hatching period, it is possible to use the reaction of the first hatch as a basis for study.[1] After the first hatch the observations were equally spaced on the logarithmic scale. Since the initial observation was 1.5 hours (arbitrarily chosen), the following intervals were 2.25, 3.38, etc., hours. The data collected at 25° C. have been included as an illustration (Table 1). At 15° and 17.5° the observations on hatching were more or less equally spaced.

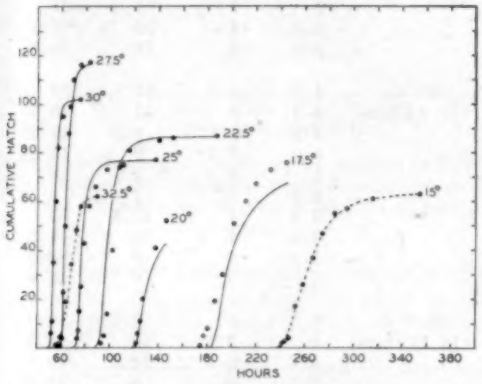

FIG. 1.—Calculated curves (lines) and actual observations (circles) for hatching of eggs of Mexican *Anastrepha fraterculus*. Broken lines connect data for 15° and 32.5° C., which are not on the regression line owing to extremes in temperature. Although 17.5° C. is not on the line, the calculated curve is shown.

The hatching range was approximately normal in its distribution when the time units were converted to logarithms, as shown by the straight lines obtained by plotting the probit of accumulative hatch in per cent against the logarithm of the hatching period.

With the calculated constants as determined by the equation presented previously by Starr,[1] hatching curves were calculated at each of the temperatures studied (Fig. 1). Agreement appears to be close. The first run at 20° gave a correct incubation period, but some factor stopped all the eggs from hatching, in consequence of which the curve was poor and the hatching range short.

[1] Shaw, J. G., and D. F. Starr, The development of the immature stages of *Anastrepha serpentina* (Wied.) in relation to temperature. [In manuscript.]

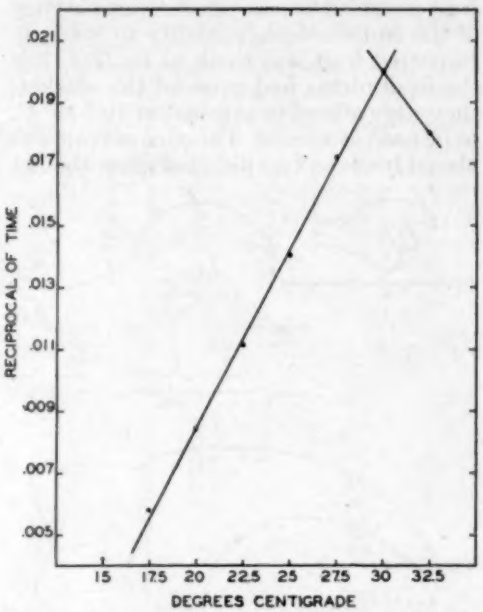

FIG. 2.—Regression line for incubation of eggs of Mexican *Anastrepha fraterculus* plotted as temperature versus the reciprocal of incubation in hours.

The effect of temperature on the hatching process may be analyzed by considering the incubation period and the hatching period separately. As shown in figure 2, the incubation period when plotted as a reciprocal against the temperature gives a straight line between 20° and 30° C. A temperature of 32.5° is definitely too high; 17.5° appears to be slightly low, for it deviates slightly from the regression line, while 15° is definitely off the line. The hatching period as recorded in table 2 is generally shorter as the temperature increases but is much more variable than the incubation period.

LARVAE.—The newly emerged larvae were removed from the incubation dishes with a camel's-hair brush and placed in notches cut in sections of plums. Plum

Table 2.—Summary of incubation and hatching tests on eggs of Mexican *Anastrepha fraterculus*.

TEMPERATURE, °C.	NUMBER INCUBATED	NUMBER HATCHED	PER CENT HATCHED	INCUBATION PERIOD, HOURS	HATCHING PERIOD, HOURS
15	219	65	28.7	239	114
17.5	152	76	50.0	172.5	62.5
20	133	52	39.1	119.5	25.7
22.5	151	87	64.2	90.0	97.7
25	139	77	55.4	71	65.7
27.5	170	117	68.8	58	25.7
30	177	102	57.6	50	25.7
32.5	165	62	37.5	54.5	34.5

fruit was used because of the transparency of the sections and its ability to hold up. Imported fruit was used, as by this time the local plums had gone off the market; they were placed in sawdust at 10°–15° C. to be used as needed. The slice of fruit was placed between two pieces of glass about 1

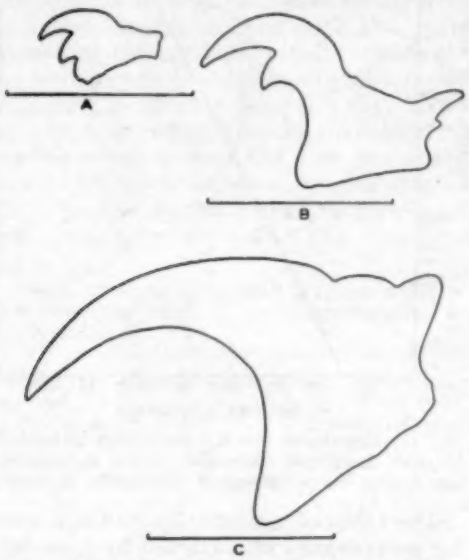

FIG. 3.—Mouth hooks of larvae of Mexican *Anastrepha fraterculus*: *A*, first instar; *B*, second instar; *C*, third instar. (Each line represents 0.1 mm.)

inch square which were sealed with paraffin except for a small hole left for ventilation.[1] A ripe, mealy fruit without too much juice was found most satisfactory, for a juicy fruit drowned the small larvae while a hard fruit prevented entrance of the larvae and retarded larval development. Because of the danger of fungus growth or desiccation of the fruit, it was necessary to change the sections at least once a day. To determine changes in larval instars it was necessary only to observe the larvae, as the mouth hooks changed at each molt. Thus it was possible to study many first instars per fruit section and remove them as they molted. This also eliminated the tedious and sometimes impossible job of finding the cast skins. Figure 3 shows the mouth hooks of all three larval instars.

Larvae were studied at 17.5°, 20°, 22.5°, 25°, 27.5°, and 30° C. At the lower temperatures the growth was so retarded that it was impossible to bring any through at 15° C. and only a few at 17.5° C. Table 3 gives the summarized results of the larval instars at the various temperatures. The larvae have to be removed from the plates before time for pupation and placed in fruit sections over sand in stender dishes; thus they are free to pupate in sand when they choose. In table 3 are shown only

[1] Stone, W. E. Unpublished data, 1936.

Table 3.—Summary of larval development of Mexican *Anastrepha fraterculus* at different temperatures.

Temperature and Graphic Median	First Instar	Second Instar	Third Instar	Total
	Days	*Days*	*Days*	*Days*
17.5° C.	7.5	4	14	25.5
(22.5 Days)	6	4.5	11.5	22.0
	6	4	11	21
	6.5	4	12	22.5
	8.5	4	12	24.5
20° C.	4.5	5.5	13	23
(17.5 Days)	4.5	5	11	20.5
	4.5	3.75	9.5	17.25
	5	3.5	8	16.5
	4	4.5	9.5	18
	4.5	3	11	18.5
	3.5	4	12.5	20
	3.5	4	10	17.5
	3.5	3	7	13.5
	5	3	8	16.0
22.5° C.	2.5	3	6.5	12
(14.75 Days)	3	3.5	10	16.5
	4	3.5	12.5	20
	3.5	3	8	14.5
	4	3	8	15
25° C.	2	3	6.5	12.5
(12.75 Days)	2	3	6.5	12.5
	3	3	7	13.0
	3	3	7	13.0
	3	3	8	14.0
	4	3	6	13.0
27.5° C.	2	1.5	8	11.5
(11.25 Days)	2	3.5	6	11.5
	2	3.5	10	15.5
	2	2	7.5	11.5
	2.5	2.75	5	10.25
	2.75	2.50	6	11.75
	2.5	2.5	7	12
	3	1.5	5.5	10
30° C.	6	3.5	6.5	16
(14 Days)	6	3.5	6.5	16
	5	2	9	14
	5	3	7.5	15.5
	5	3	8.5	16.5
	5	3	8	16
	5	3	8	16
	2.5	1	7	10.5
	2.5	2.5	7.5	12.5
	2.5	1.5	8.5	12.5
	2.5	3	8.5	14
	2.75	1.5	8	12.25
	3.5	2	7	12.5

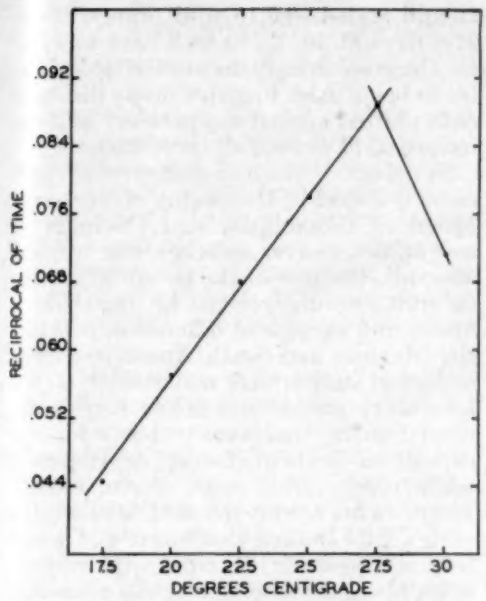

FIG. 4.—Regression line for larval duration of Mexican *Anastrepha fraterculus* plotted as temperature versus the reciprocal of graphic median of time in days.

those larvae which completed all the molts and not the great number that lived through only one or two stages. Above 27.5° C. the temperature had an inhibitory effect on larval development. Figure 4 shows the duration of the larval period in the plum sections as temperature plotted against the reciprocal of the median time.

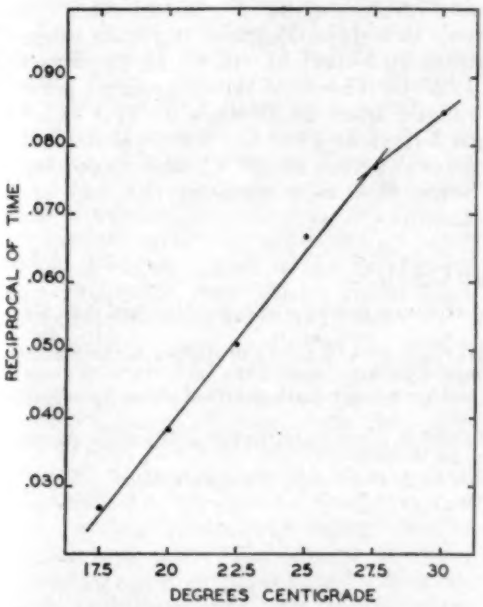

FIG. 5.—Regression line for duration of pupal stage of Mexican *Anastrepha fraterculus* plotted as temperature versus the reciprocal of graphic median time in days.

Table 4.—Summary of puparial development of Mexican *Anastrepha fraterculus* at different temperatures.

17.5° C.			20° C.			22.5° C.		
Days	*Number* ♂	♀	*Days*	*Number* ♂	♀	*Days*	*Number* ♂	♀
35	1		23.5		1	17.5	2	
36	2	5	24.5	2		18	2	1
37	2	6	25.5	4	2	19	2	4
37.5	1	2	26	2	5	19.5	2	3
39	1	1	26.5	3	6	20	10	15
40	1		27	1	3	20.5		5
40.5	5	1	27.5	1	1	21		2
41	1		29		1			
42.5	2		31	1				
			32.5	1				
Per cent emergence = 86.5 25° C.			Per cent emergence = 89.7 27.5° C.			Per cent emergence = 100 30° C.		
Days	*Number* ♂	♀	*Days*	*Number* ♂	♀	*Days*	*Number* ♂	♀
11.5	1	6	12.5	6	5	10.5	1	
12	4	1	13	19	11	11		1
12.5	5	3	13.5	15	15	11.5	8	6
13	1		14	2	6	12	13	10
13.5	1	1	14.5	1		12.5	4	6
14	2	2	16	1		13	1	
15.5	11	11				15	1	1
16	8	8				16		1
16.5	5	1				21	1	
17	5	1						
18	1	1						
18.5		1						
21		1						
Per cent emergence = 100			Per cent emergence = 97.7			Per cent emergence = 98.2		

PUPARIA.—Results of the tests on the puparium at the various temperatures are shown in table 4. Puparia were placed in moist sand in small glass jars with a loosely fitting cover and held at the desired temperature for fly emergence. The shortest time was 10.5 days at 30° C. and the longest was 42.5 days at 17.5° C. Figure 5 shows the regression line plotted as temperature versus the reciprocal of the graphic median time. The line starts to break at 27.5° C., which seems to indicate this as being close to the optimum temperature.

Table 5.—Summary of data on developmental period of Mexican *Anastrepha fraterculus*.

TEMPERATURE °C.	GRAPHIC MEDIAN OF DURATION IN DAYS			
	Eggs	Larvae	Puparia	Total
17.5	7.9	22.5	37.1	67.5
20	5.35	17.5	26	48.85
22.5	4.16	14.8	19.8	38.76
25	3.24	12.75	15	30.99
27.5	2.63	11.3	13	26.93
30	2.26	14	11.8	28.06

Although the majority of the flies usually emerge in the morning, emergence takes place during the entire day.

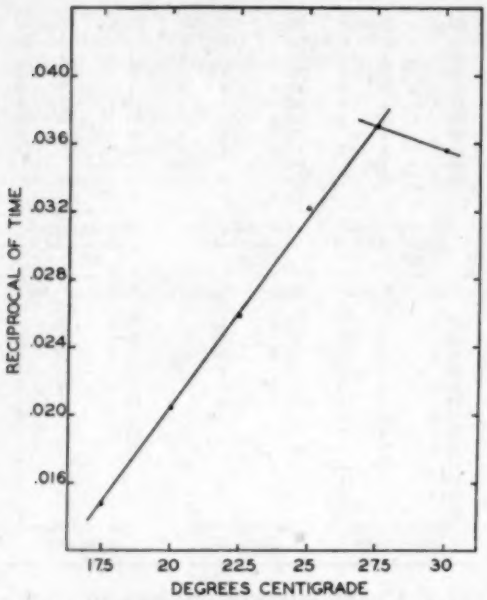

FIG. 6.—Regression line for the developmental period of the immature stages (eggs, larvae, and puparia) of Mexican *Anastrepha fraterculus* plotted as temperature versus the reciprocal of total graphic median time in days.

LENGTH OF ADULT LIFE.—No tests were run at constant temperatures, but some flies were alive at the end of 8 months. They were used for fruit-infestation and oviposition studies and kept mostly at room temperature.

TOTAL LENGTH OF DEVELOPMENTAL PERIOD.—The total length of the developmental period, egg to adult, ranged from 27.2 days at 30° C. to 66.2 days at 17.5° C., the graphic medians of each stage (Table 5) being used. Figure 6 shows the same data plotted against temperature and the reciprocal of days of all three stages.

SUMMARY.—Mexican *Anastrepha fraterculus* is found in the States of Veracruz, Morelos, Tamaulipas, and Coahuila in rose apples, guavas, peaches, and tropical almonds. Because of the potential danger to fruit-growing regions of the United States and because of differences between the Mexican and South American forms, biological studies were undertaken. In the laboratory grapes and coffee berries appeared to be the favorite hosts for egg deposition without larval development while peach, jobo, pear, guava, loquat, and plum are readily infested. Diet studies with adults showed that sugar and water were sufficient for life, but for the acceleration of egg development it was necessary to add a protein. The first mating was seen on the sixteenth day and the first eggs were laid on the twentieth day. The incubation period of eggs ranged from 50 hours at 30° C. to 239 hours at 15° C.; at 32.5° C. the incubation period was 55.5 hours. Larval duration in plum sections ranged from 10 days at 27.5° C. to 21 days at 17.5° C.; at 30° C. the shortest time was 10.5 days. Puparial duration ranged from 10.5 days at 30° C. to 35 days at 17.5° C. The total developmental period ranged from 26.93 days at 27.5° C. to 67.5 days at 17.5° C.; the total developmental period at 30° C. was 28.06 days. Some flies were alive at the end of 8 months.

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Control of Mexican Bean Beetle and Corn Earworm in the Presence of Powdery Mildew on Snap Beans

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Experiments on the fall crop of snap beans in eastern Virginia for control of the Mexican bean beetle, *Epilachna varivestis* (Muls.), are often complicated by infestations of the corn earworm, *Heliothis armigera* (Hbn.), and powdery mildew disease, *Erysiphe polygoni* DC. The combined effect of the insect and disease attacks on the crop production is oftentimes severe.

The value of sulfur dusts and sprays in controlling powdery mildew disease on snap beans has been demonstrated by Cook (1931) and Cook & Nugent (1940). Brannon & Howard (1936) had shown that sulfur in combination with rotenone and cryolite dusts and sprays was effective for the control of the Mexican bean beetle and powdery mildew. The author (Brannon 1939, 1941) has reported on the use of cryolite for control of the corn earworm on beans.

With these results as a background, the object of the experiment reported herein was to determine the comparative effectiveness of combinations of derris and sulfur and cryolite and sulfur for the control of the two insects and the disease.

PROCEDURE.—The experiment was conducted on the Bountiful variety of snap beans, *Phaseolus vulgaris* (L.), at Norfolk, Va., in the fall of 1941. Each plot in the experiment contained four rows 90 feet long and 30 inches apart. The plots for the various treatments were randomized in four blocks, the plot for each kind of treatment occurring once within each block. Thus each plot in the experiment was replicated four times. Each block also contained one untreated plot.

The sprays were applied at the rate of approximately 140 gallons per acre by use of a 4-row power sprayer equipped with a 4-row "horseshoe" boom with three nozzles to each row and operated at a pump pressure of 250 pounds. Dusts were applied with a 4-row power duster equipped with two bean beetle-type "scoop" nozzles to each row, and with a light cloth trailer extending approximately 12 feet to the rear. Cryolite dust mixtures were applied at the rate of 17 pounds per acre and the derris dust at the rate of 28 pounds per acre.

Applications were made on September 17 and October 2. At the time of the first application the plants were budding, no blooms having been observed, and at the time of the second the plants were in full bloom. Counts for Mexican bean beetle infestation made on the 4 random plots on September 15 (2 days prior to the first application) indicated an average infestation of 12 beetles, 7.5 egg masses, and 2.5 hatching egg masses on 25 feet of row. Additional counts made on the same plots on September 22 indicated an average infestation of 44 beetles, 5.5 egg masses, 3.75 newly-hatched egg masses, and 3 batches of young larvae on 25 feet of row. The white fungus causing powdery mildew disease was first observed on the foliage of the plants on September 15, 2 days prior to treatment. It spread rapidly and caused severe damage to both the foliage and pods, damage to the latter being especially noticeable at the time of the second picking of the crop.

The first corn earworm eggs were also found on the leaves of the plants on September 15, seven eggs and two larvae one-half inch long being found on 50 plants selected at random in the field. The beans were picked on October 13 and 22. In order to obtain data with respect to the combined damage caused by the Mexican bean beetle, corn earworm, and powdery mildew disease, the beans on all plants on a 44-foot length sampling area on the second row of each 4-row plot were weighed, examined, and counted, records being made of the injured and the uninjured pods. This involved the examination of 14,716 pods for the 2 pickings of the crop.

RESULTS.—The results of the experiment are presented in table 1. The data in table 1 show that cryolite-sulfur dust (70 per cent sodium fluoaluminate) gave significantly higher yields than cryolite-talc having the same sodium fluoaluminate content. Since the two materials gave comparable results against the Mexican bean beetle and the corn earworm, the difference may no doubt be attributed to the value of sulfur against powdery mildew disease. Cryolite-sulfur dust also gave a significantly higher yield than derris-sulfur (0.50 per cent rotenone). As indi-

[1] In cooperation with the Virginia Truck Experiment Station.

Table 1.—Effectiveness of various insecticidal treatments for the control of the Mexican bean beetle, corn earworm, and powdery mildew disease on snap beans.

Insecticides Used	Rate per Acre	Marketable Beans per Acre	Per Cent Wormy Pods per Plot	Estimated Bean Beetle Injury to Foliage[1]
Dusts:	*Pounds*	*Bushels*		*Per Cent*
Cryolite[2]-sulphur (70 per cent sodium fluoaluminate)	17	116	3.2	2
Cryolite[2]-talc (70 per cent sodium fluoaluminate)	17	88	3.0	2
Derris[3]-sulphur (0.50 per cent rotenone)	28	88	20.9	2
Sprays:	*Gallons*			
Cryolite[2]—3.81 pounds,[4] wettable sulfur 2 pounds, water 50 gallons	143	95	10.8	3
Derris root powder,[3] wettable sulfur (0.015 per cent rotenone)[5]—2 pounds, water 50 gallons	137	76	18.8	2
Untreated	—	49	28.2	58
Difference required for significance, 5% level	—	15	4.1	—

[1] Based on final records taken 3 weeks after the second insecticidal treatment.
[2] Synthetic cryolite. Fluorine content 48.5 per cent, equivalent content of cryolite (sodium fluoaluminate) 80.3 per cent (I.D. No. 4760).
[3] Rotenone content of derris 4.4 per cent. Total extractives (chloroform) 14.1 per cent (I. D. No. 4759).
[4] Equivalent to 4 pounds of cryolite containing 85 per cent of sodium fluoaluminate in 50 gallons of water.
[5] Equivalent to 1.56 pounds of derris of 4 per cent rotenone content in 50 gallons of water.

cated from previous work, this resulted from the fact that although both the cryolite-sulfur dust and derris-sulfur dust gave comparable control of the Mexican bean beetle and powdery mildew, derris was not effective against the corn earworm. It will be noted that cryolite-sulfur dust gave significantly higher yields than cryolite-wettable sulfur spray. This no doubt resulted from the difference in quantities of sodium fluoaluminate applied (Table 1), approximately 22 per cent more having been applied per acre in the dust mixture than in the spray. Differences between derris dust and derris spray were not significant. The uniformity of the corn earworm infestation in the plots is indicated by the comparative percentage of wormy pods on derris dust, derris spray, and untreated plots. These results also confirm previous results as to the ineffectiveness of rotenone sprays and dusts against the corn earworm.

At the conclusion of the experiment the foliage of the plants on the untreated plots, and on plots treated with cryolite in which talc was the diluent, was stunted and completely covered with the white fungus causing powdery mildew disease, whereas plants in plots that had received treatments containing sulfur (either in combination with the sprays or as a diluent for the dusts) remained green and healthy. Also, a large percentage of the pods on plants that failed to receive treatments of sulfur were unmarketable owing to injury resulting from the disease, the pods on such plants being dwarfed, deformed, and badly spotted with reddish-brown lesions. This damage was especially noticeable at the time of the second picking of the crop.

The results of the experiment indicate that in instances where Mexican bean beetle and corn earworm infestations occur in association with powdery mildew disease on snap beans, cryolite should be used in preference to derris for the combined control of the two insects, and sulfur should be used as a diluent for the dust (or in combination with the spray) in preference to talc or other diluents for its value against mildew. In case the corn earworm is not present, a derris-sulfur dust or spray may be substituted for cryolite.—12-7-44.

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Gambrus stokesii Cam., an Australian Parasite of Codling Moth and Oriental Fruit Moth

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The parasite *Gambrus stokesii* Cam. was reported by Miller (1938) and Helsen (1939) as parasitic in Australia on pupae of both the codling moth *Carpocapsa pomonella* (L.), and the oriental fruit moth *Grapholitha molesta* (Busck). Through the courtesy of the Council for Scientific and Industrial Research of the commonwealth of Australia, 201 cocoons of this parasite were received at the Moorestown, N. J., laboratory of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in March 1938. From these cocoons a total emergence of 138 adults, of which 31 were females, was obtained during the period March 29 to April 14, inclusive.

Previous attempts to propagate this parasite on the oriental fruit moth at Moorestown, following small importations, had been unsatisfactory because the ratio of females produced was very unfavorable. During the spring and the early part of the summer of 1938 an attempt was made to ascertain whether the sex ratio could be improved by utilizing the larger of the known host species, the codling moth, as previous work by others, notably Chewyreuv (1913) and Brunson (1938), had indicated that in work with certain other parasites a greater proportion of females had developed from larger hosts than from smaller ones. It was desired, if possible, to develop a suitable technique for mass breeding, in order to obtain adults in numbers sufficient for colonization. Observations on the development and habits of the parasite under laboratory conditions and a discussion of the results obtained from experimental and routine breeding work conducted during 1938 and 1939 are presented in this paper.

In breeding *Gambrus stokesii* it was found that the females oviposited readily when confined in a wooden cage 11 by 4.75 by 7 inches in size, having a cotton-gauze back and a removable glass front. Absorbent cotton saturated with a 10-per cent solution of honey in water was provided as food for the parasites. Pupae of the host species within cocoons spun in sections of semitransparent, white, corrugated paper were placed in shallow trays of black paper set on the floor of the cage and exposed to attack by the female parasites for periods of 24 or 48 hours. On removal from the cages, the cocoons were torn open and the parasite eggs were shaken into the bottom section of a petri dish, the inside of which was painted black so that the white eggs could be readily seen. With the aid of a camel's-hair brush the eggs were then placed, one to each host insect, in No. 3 gelatine capsules supported in an upright position in a rack formed of quarter-inch mesh hardware cloth attached to a wooden frame. Parasite larvae that hatched from eggs originally deposited in cocoons containing oriental fruit moth pupae were thus reared on pupae of the oriental fruit moth and the codling moth. *Gambrus* larvae from eggs that had been deposited in cocoons containing codling moth pupae were also reared on pupae of both the oriental fruit moth and the codling moth. Other *Gambrus* larvae were reared on hibernating larvae of either host species, the host having been rendered inactive by immersion for 5 minutes in water, the temperature of which was maintained at 54° C.

Earl Lott, formerly of the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture, in conducting somewhat similar experiments in breeding other species of codling moth parasites at the Moorestown, N. J., laboratory, had previously found that overwintering codling moth larvae could be satisfactorily paralyzed by the above-mentioned technique.

Adults of *Gambrus stokesii* mate readily and the females are long-lived and very prolific. Seven fertilized females, confined individually in 1- by 5-inch glass vials, supplied with food in the form of a 10-per cent solution of honey in water, and held in laboratory rooms at a temperature of 70°–80° F., remained alive an average of 41 days, the maximum longevity being 75 days. From the date of fertilization until death occurred these 7 females were pro-

vided daily with renewed supplies of either codling moth or oriental fruit moth pupae within cocoons. They deposited an average of 116.1 eggs each, a maximum of 224 eggs being deposited by 1 female.

The preoviposition period is from 24 to 48 hours in duration. The optimum conditions for egg production were found to be temperature ranging from 70°–80° F. accompanied by relative humidity of 60–80 per cent. The female parasites oviposited readily in cocoons containing pupae of either the codling moth or the oriental fruit moth; however, a definite preference for codling moth cocoons was indicated. When equal numbers of cocoons containing pupae of these host species were exposed together to attack by the same *Gambrus* females on different occasions for periods of approximately 48 hours, from 75 to 100 per cent, or an average of 91 per cent, of the eggs were deposited in cocoons containing codling moth pupae. Only occasionally were eggs deposited in cocoons containing hibernating codling moth larvae, and none were deposited in cocoons containing pupae of the European corn borer, *Pyrausta nubilalis* (Hbn.), exposed under laboratory conditions.

The egg of *Gambrus stokesii* averages approximately 0.96 mm. in length by 0.28 mm. in width, and is broadly rounded at the cephalic end and more acutely rounded at the caudal extremity. The eggs are deposited within the host cocoon, which is pierced by the ovipositor of the female parasite, and remain loose within the cocoon and usually are not in contact with the host. In these propagation studies as many as 20 eggs were deposited by 1 female within 24 hours in a single cocoon containing a codling moth pupa. In many instances, when several cocoons containing codling moth pupae were available in the oviposition cages, all or most of the parasite eggs were found in 1 or 2 cocoons and few or none in the others.

At a temperature of 80° F. the minimum incubation period was found to be 30 hours and the average period was approximately 31 hours. At 70° eggs began to hatch in about 50 hours from the time of deposition. *Gambrus* eggs a few hours old have been held in storage at 42° for as long as 48 hours, in order to delay hatching, and only slight mortality resulted. The mortality of eggs stored for a longer period, however, was considerable.

The newly hatched larva of *Gambrus stokesii* is canibalistic and will attack and feed upon, thereby destroying, all larvae of its own kind that it encounters. Because of this tendency it is necessary to isolate the eggs prior to hatching, when breeding this species in the laboratory. The young larva of this ectoparasite usually attacks the pupa of the host species at the junction of two abdominal segments or under the apex of the wing covers. By the time the parasite larva has attained the third instar its feeding is confined entirely to the latter point and eventually its entire head and anterior portion penetrate the body of the host pupa beneath the wing covers. When reared on inactivated host larvae the parasites may feed at any point in the soft integument of the host. The feeding period of *G. stokesii* larvae reared at 80° F. on pupae of the oriental fruit moth or the codling moth averaged about 4.5 days, the time required for feeding being prolonged about 1 and 3 days, respectively, for those reared on inactivated larvae of the two host species. This parasite has five instars.

A larva of *Gambrus stokesii* reared on a codling moth pupa usually constructs a substantial cocoon within the empty pupal shell of the host. The pupal shell becomes distended and broken by the entrance and movements of the large parasite larva, but the fragments adhere to the white threads of the parasite cocoon and serve as partial protection around it. Larvae reared on pupae of the oriental fruit moth, which are smaller than codling moth pupae, frequently abandon the host shell when mature and surround themselves with a few loosely woven silk-like threads, which serve as a cocoon. When reared on an inactivated larva of the host species the parasite larva abandons the shriveled remains of the host when mature and likewise encloses itself within a cocoon of loosely woven threads.

Change to the prepupal stage takes place in 2 or 3 days after completion of feeding for *Gambrus* larvae reared on either pupae or inactivated larvae of the oriental fruit moth, and in 4 or 5 days after feeding is completed when reared on pupae or inactivated larvae of the codling moth. The transformation of the parasite to the pupal stage usually occurs about 24

hours after the prepupa is first observed. By moving the abdomen in a circular motion the pupa rotates itself on its longest axis, first in one direction, then in the other. This is done, apparently, in order to form a cell within the loosely spun threads of the cocoon. The length of the pupal period averages 5 to 6 days at 80° F. The species of host on which the parasite larva is reared appears to have no effect on the duration of this stadium. The adult parasite makes its exit through a hole which it chews in the end of the cocoon.

The completion of the life cycle of *Gambrus stokesii* reared on different hosts at approximately 80° F. required from 13 to 24 days. The shortest average life cycle, 15 days, was observed among those reared on pupae of the oriental fruit moth; 17 days was the average life cycle of those reared on codling moth pupae and also for those reared on inactivated larvae of the oriental fruit moth; and an average of 21 days was required for the life cycle of those reared on inactivated codling moth larvae. Usually the development of the female was slightly slower than that of the male.

Attempts to rear *Gambrus stokesii* by placing unhatched eggs in capsules with normal hibernating larvae of either the codling moth or the oriental fruit moth, or with pupae of the European corn borer, were unsuccessful, indicating that neither of these is a suitable host for this parasite.

In order to maintain a breeding stock, 270 *Gambrus stokesii* were placed in cool storage at 42° F. as soon as the mature larvae completed construction of their cocoons. Sixty per cent of the cocoons thus stored for as long as 9 months subsequently produced adults. Comparatively few individuals survived when similarly stored after having attained the prepupal or the pupal stadium, therefore it is very probable that this parasite hibernates as a mature larva.

It will be noted from the rearing records summarized in table 1 that, with one exception, a decidedly greater percentage of female parasites developed from eggs that had been deposited in cocoons containing codling moth pupae than from those deposited in cocoons containing oriental fruit moth pupae, regardless of the species of host pupae on which the parasite larvae were subsequently reared. The records indicate that a much lower percentage of female parasites emerged from *Gambrus* larvae reared on inactivated oriental fruit moth larvae than from those reared on inactivated codling moth larvae, although the eggs in both instances had been deposited in cocoons containing codling moth pupae. A total of only 20 parasites were reared on inactivated larvae of the smaller host species, however, and two oriental fruit moth larvae were required to complete the development of each.

Table 1.—Adults of *Gambrus stokesii* reared at Moorestown, N. J., during 1938 and 1939.

Gambrus Eggs Deposited in Cocoons Containing Pupae of—	Larvae Reared on—	Parasites that Emerged	
		Total	Females
		Number	*Per Cent*
Oriental fruit moth	Oriental fruit moth pupae	81	13.6
	Codling moth pupae	50	12.0
Codling moth	Oriental fruit moth pupae	655	40.3
	Codling moth pupae	4650	43.0
	Oriental fruit moth inactivated larvae	20	15.0
	Codling moth inactivated larvae	705	38.0
Oriental fruit moth	Various hosts	131	13.0
Codling moth	Various hosts	6030	42.0

The results of these breeding experiments indicate that the sex of the progeny of *Gambrus stokesii* is apparently fixed at the time the egg is deposited in the cocoon of the host and is not appreciably affected by the type or quantity of food available to the developing larva. This conclusion is in line with the findings of Brunson (1938), who reported on the rearing of *Tiphia popilliavora* Roh., an imported parasite of the Japanese beetle, *Popillia japonica* Newm. It is also apparent that the codling moth is a more suitable host than the oriental fruit moth for development of *G. stokesii*.

Breeding work carried on during the 2 years 1938 and 1939 resulted in the production of 6447 adults, of which 2647 were females. Including 2 small releases made in 1933 of adults reared from direct importation, a total of 2585 females of *Gambrus stokesii* had been released by the end of 1939 in 31 colonies placed in 27 localities in the following States: Connecticut, New York, New Jersey, Delaware, Virginia, West Virginia, Kentucky, Georgia, Ohio, Indiana, Illinois, Michigan, and Idaho. Many of the liberations were made by members of cooperating State agencies to which the adult parasites were shipped,

and most of the colonies were placed either in orchards with peach and apple interplanted or at points where peach and apple plantings adjoined. No attempts to determine establishment of this parasit have been made.—11-30-44.

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Relation of Insect Damage to Thiamine Content of Biscuits[1]

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Hard biscuits of the type issued to the armed forces as emergency rations must frequently be stored for long periods during which insects may be an important cause of spoilage. If the biscuits favour the development and survival of insects feeding on them, extensive damage may occur; and to the extent that they are unfavorable, the biscuits will be resistant to insect attack.

Smallman & Aitken (1944) investigated the susceptibility of such biscuits to insect damage and found that larvae of the flour beetle, *Tribolium confusum* Duv., suffered a high mortality, and development was greatly retarded on the biscuits as compared with control insects on flour. Varying the moisture content and principal ingredients of the biscuits produced only minor changes in the survival and development of insects feeding on them. The authors concluded that the nutritional value of the main ingredient, flour, had been altered during the baking process, and this had rendered the biscuits an unsuitable food for the insects. They suggested that loss of thiamine was probably responsible.

This study was designed to investigate the nature of the deficiency which prevented normal development of insects on the biscuits. Changes in the nutritional value of flour, induced during the baking process for biscuits, were related to corresponding changes in the growth, development, and oviposition rates of insects. The data show that merely baking the flour, especially in the presence of an alkaline salt, resulted in loss of thiamine and a sharp reduction in ability to support the normal development and reproduction of *Tribolium*.

MATERIALS.—The biscuit formula was: flour, 100 gm. (13.5 per cent moisture basis); cane sugar, 5 gm.; milk powder, 8 gm.; baking soda, 1.5 gm.; salt, 1.5 gm.; fat (hydrogenated peanut oil), variable; and distilled water, 38 ml. The flour was of 85 per cent extraction. Two batches of biscuits, one containing 2 gm. of fat and the other 12 gm. of fat, were made by baking for 12 minutes in an oven maintained at 230° C.

In order to determine whether the nutritional value of the flour was altered by the high temperature during the baking process, biscuits were made with only the flour and water components of the complete formula. A portion of this paste was baked for 12 minutes at 230° C.; the remaining paste was allowed to dry partially and then baked for the same time to produce overbaked biscuits. Similarly, biscuits containing only the flour, water, and baking soda components of the formula were prepared and baked in the same way as the complete biscuits. All biscuits were then ground in a Wiley mill to pass a 0.5 mm. sieve. These materials were placed in a dessicator maintained at 75% R. H. and reached equilibrium at an average moisture content of 12.0 per cent (11.5%–12.9%). A sample of flour was similarly brought to 12.3% moisture content.

The test insect was the confused flour

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beetle, *Tribolium confusum* Duv. All experiments were carried out at 27° C.

RESULTS.—*Growth and Development*: Twenty newly-hatched larvae of *Tribolium confusum* were reared on each of the baked materials and on flour. After 30 days the growth of the larvae was determined by measuring their length. The rates of development on the various materials were assessed by comparisons of the length of time required to achieve pupation.

The growth of *Tribolium* larvae was retarded on all the baked materials. The results are shown in figure 1. All larvae reared on flour had pupated at the end of

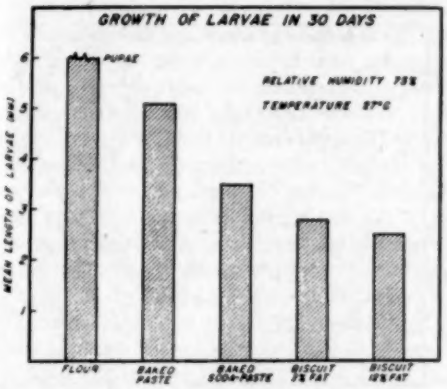

FIG. 1.—Growth of *Tribolium* larvae in 30 days.

30 days. During the same period none of the larvae feeding on the baked flour and water paste had pupated; however, they had achieved a substantial growth, and had an average length of 5.1 mm. On the baked soda-paste the growth of larvae was sharply reduced to an average length of 3.5 mm. Larvae feeding on complete biscuits containing 2 per cent and 12 per cent fat suffered a further reduction in growth, achieving an average length of 2.8 mm. and 2.5 mm. respectively in 30 days.

The rate of development of *Tribolium* larvae was likewise retarded on the baked materials. The results are shown in figure 2. The time required to achieve pupation was increased, and the number surviving to pupate decreased, as the flour was modified by the process of biscuit-making. On flour, all larvae had pupated in 27 to 30 days, while on the baked paste only half the larvae survived to achieve pupation in a period of 54 to 69 days after hatching

Larvae reared on the baked soda-paste required 78 to 139 days before pupation occurred and only 9 out of 20 survived to this stage of development. On complete

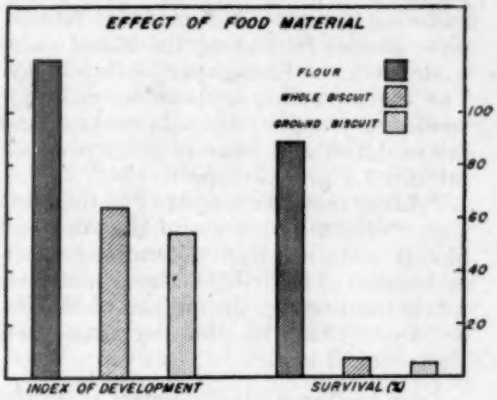

FIG. 2.—Rate of development of *Tribolium* larvae.

biscuits containing 2 per cent fat only 2 out of 20 larvae had pupated in 101 to 131 days after hatching, and on biscuits containing 12 per cent fat there were no pupae at 140 days after hatching.

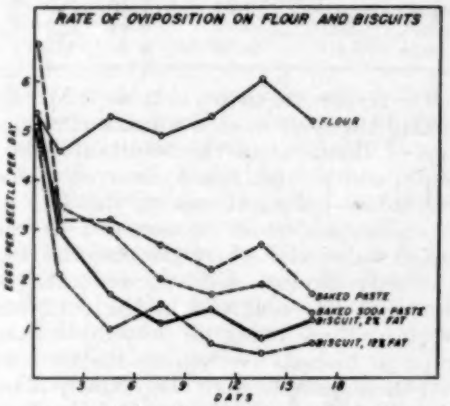

FIG. 3.—Rate of oviposition of *Tribolium*.

Oviposition: The rate of oviposition was determined, with 5 female beetles on each of the biscuit materials and a flour control. The number of eggs produced was recorded in terms of eggs per beetle per day, for six periods of 3 days each; at the end of each 3-day period the eggs were removed by sifting the flour and ground biscuit materials.

The rate of oviposition on the baked materials was reduced in the same order as the growth and development of the larvae. The results are shown in figure 3.

On flour, oviposition remained more or less constant at about 5 eggs per beetle per day. On baked paste, oviposition fell off rapidly and only 1.7 eggs per beetle per day were produced in the 3-day period following 15 days on this material. At that time, beetles feeding on the baked soda-paste produced 1.3 eggs per beetle per day. The corresponding oviposition rates for beetles on complete biscuits containing 2 per cent fat, and biscuits of 12 per cent fat were 1.2 and 0.7 respectively.

Effect of thiamine content: The thiamine and riboflavine contents of the flour and biscuit materials were determined fluorimetrically. The pH of these materials was determined by the method of McKim & Moss (1943) on the Beckman glass electrode pH meter.

Table 1.—The B-vitamin content and pH of flour and biscuit materials.

	Thiamine μ gm./gm.	Riboflavine μ gm./gm.	pH
Flour	3.88	0.98	6.45
Baked paste	2.90	1.11	6.02
Overbaked paste	1.25	—	5.32
Baked soda-paste	0.34	1.50	9.52
Biscuit, 2% fat	0.70	2.41	7.28
Biscuit, 12% fat	0.00	3.14	7.14

The results are shown in table 1. Merely baking the flour caused a marked reduction of thiamine in the resultant baked paste; and a further loss occurred in the overbaked paste. However, the loss of thiamine was most pronounced in the baked soda-paste where the material was distinctly alkaline. A drastic reduction of thiamine also occurred in the complete biscuits, there being no detectable thiamine in biscuits containing 12 per cent fat; these biscuits were also slightly alkaline. The riboflavine content of the flour and baked pastes was about the same; and with the addition of milk powder, in the whole biscuits, actually increased. The relation between the thiamine content of the flour and baked materials, and the oviposition of beetles feeding on them is shown in figure 4. As the thiamine content of the food was reduced, oivposition fell off rapidly at first and then more slowly as the thiamine content reached values below 2 μ gm. per gm.

Effect of molds: In another experiment, whole biscuits stored at 85 per cent R. H. developed mold growth, whereas no molds appeared on similar biscuits stored at 75 per cent R. H. This suggested a means of determining whether the growth of molds had any effect on the nutritive value of the biscuits for insects. Accordingly, whole biscuits of 2 per cent and 12 per cent fat, in duplicate, were stored at 75 per cent R. H., and 85 per cent R. H., and 10 newly-hatched larvae were placed on each biscuit. After 110 days comparisons were made of the number of progeny that had developed on the moldy and non-moldy biscuits.

The growth of molds on the biscuits stored at 85 per cent R.H. stimulated the reproduction of *Tribolium*. After 110 days, the original 40 beetles placed on these bis-

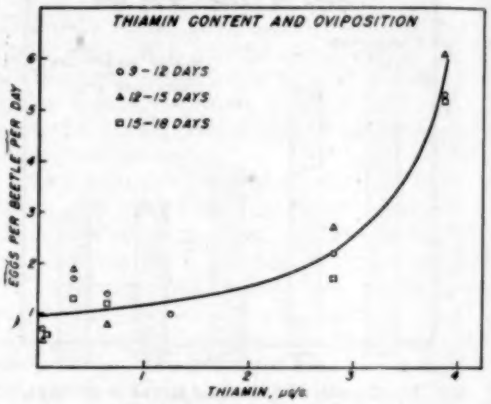

FIG. 4.—Relation of thiamin content of food to oviposition of *Tribolium*.

cuits had produced 54 progeny; eight were mature larvae, and there was one pupa, and two newly-emerged adults. In contrast, no progeny were produced by the same number of beetles on similar biscuits stored at 75 per cent R.H. where no molds developed. The increased reproduction on moldy biscuits was not accompanied by an increase in thiamine content. The non-moldy biscuits had a thiamine content of 0.45 μ gm. per gm. while the moldy biscuits yielded 0.37 μ gm. per gm.

DISCUSSION.—The primary biological functions of growth, development, and oviposition of the flour beetle, *Tribolium confusum* Duv., are all adversely affected when the normal food, flour, is baked to produce biscuits. Merely baking the flour as a paste renders it an unsuitable food for the insects and this effect is more pronounced when the paste is made alkaline by the addition of baking soda. The re-

sults show that baking the flour results in a loss of the thermolabile substance, thiamine, and that this loss is greatly increased when the flour is baked on the alkaline side; others have reported similar findings (Copping 1937; Barackman 1942). These results suggest that thiamine is required by the insects and that its destruction in the process of biscuit-making is chiefly responsible for the observed retardation of their development and reproduction.

Sweetman & Palmer (1928) found that vitamins of the B-complex were required for the normal development of *Tribolium confusum*, and Street & Palmer (1935) indicated thiamine as one of the necessary factors. Fraenkel & Blewett (1943) reared *Tribolium* larvae on an artificial diet from which all chemically identified members of the B-complex, added in pure form, were withheld one at a time. When thiamine was omitted from this otherwise adequate diet, pupation was delayed to a period extending from 55 to 132 days instead of the normal period of 27 to 29 days. This result is in reasonable agreement with the present study where larvae reared on baked soda-paste very low in thiamine (0.34 μ gm./gm.), required 78 to 139 days to achieve pupation. Nevertheless, there are indications that the deficiency in the baked materials is more acute than that obtained when thiamine alone is omitted from the diet. With thiamine as the only deficient factor, Fraenkel and Blewett still obtained 17 pupae from 20 larvae during 132 days whereas, on the baked soda-paste only 10 out of 20 larvae pupated during 139 days. This suggests that some other member of the B-complex may have been altered by the baking process. Riboflavine is also required by *Tribolium* (Fraenkel & Blewett 1943) but the results indicate no decrease in the riboflavine content of the baked materials. It seems clear, therefore, that the observed destruction of thiamine is chiefly responsible for the low rate of development and reproduction of *Tribolium* on the biscuits, although other factors may be involved. Other common insect pests of stored products would be expected to do poorly on the biscuits, since *Ptinus tectus* Boield., *Lasioderma serricorne* Fab., and *Sitodrepa panicea* L., all require thiamine in their food (Fraenkel & Blewett 1943).

With the growth of molds, the nutritional deficiency of the biscuits for *Tribolium* was offset, as indicated by the marked increase in the number of progeny produced on moldy biscuits. This result suggests that the molds had supplemented the low thiamine content of the biscuits; but there was no detectable increase in the thiamine content of moldy, over non-moldy, biscuits. Nevertheless, the molds may have synthesized thiamine (Bonner & Buckman 1939) in minute quantities which could not be detected in the analysis of the gross biscuit material. Preferential feeding on the molds, would then enable the insects to offset the thiamine deficiency of the biscuits and to produce numbers of progeny, as observed. It may be of practical importance to note that while biscuits of this type are remarkably resistant to insects they may still serve as a source of infestation if they become moldy.

The fat content of the biscuits seems to have an unfavorable effect on *Tribolium*. Growth, development and oviposition are all retarded to a greater extent on the complete biscuits containing fat, than on the baked soda-paste; and this retardation is more pronounced as the fat content is increased from 2 per cent to 12 per cent. This effect can hardly be attributed to thiamine deficiency, since the thiamine content is already at a very low level in the baked soda-paste. Sweetman & Palmer (1928) found that the addition of butterfat or *Crisco* to an adequate diet actually accelerated the growth of *Tribolium* larvae. At present, no explanation is offered for the adverse effect on the insects, apparently induced by the fat content of the biscuits.

SUMMARY.—This study was undertaken in order to determine the nature of the deficiency in army ration type biscuits, which made them resistant to the confused flour beetle, *Tribolium confusum* Duv. Flour was modified, as in the process of biscuit-making, first by baking it as a flour-water paste, and then by baking as a paste containing the baking soda component of the biscuit formula. The growth, development and oviposition of *Tribolium* feeding on these materials and on complete biscuits containing 2 per cent and 12 per cent fat was determined and related to changes in thiamine content induced by the baking process. Baking

the flour, especially when it was made alkaline by the addition of baking soda, resulted in the destruction of thiamine and a marked reduction in ability to support the normal growth and reproduction of the insects. The growth of molds on the biscuits caused an increase in the reproduction of *Tribolium*. In addition to the adverse effect on the thiamine deficiency, the fat content of the biscuits appeared to be unfavorable to the insects.[1]

[1] The author wishes to acknowledge the assistance of Mr. W. J. Eva, Assistant Chemist, Grain Research Laboratory, who made the thiamine determinations, and Mr. A. Hoffer, Western Canada Flour Mills, who made the riboflavine determinations. Thanks are also due to Mr. B. Berck, Laboratory Assistant, for his help throughout this work.

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Squash Bug Depredations in Washington[1]

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Since 1937 the squash bug (*Anasa tristis* (DeG.)) has been invading central Washington in outbreak proportions. The insect was first reported in Washington at Underwood on the Columbia River in 1921. It was not until 1937, however, when the pest appeared at Kennewick, near the mouth of the Yakima River, that serious trouble resulted. The spread from Kennewick has been west through the entire Yakima Valley, then northeast to Ephrata and Wilson Creek and to the east through the Walla Walla Valley to Clarkston. Squash production throughout the area bounded by these points has practically ceased, both in the home garden and on a commercial scale because nearly all squash planted withered and died as a result of squash bug feeding.

Very few squash were ever produced in the vicinity of Underwood, but in the irrigated Yakima Valley squash constituted an important crop of more than 1000 acres. Marblehead, a winter squash, is the main variety grown because it is resistant to curly top disease (western yellow blight). In addition, Marblehead is a very productive variety, both in size and number of fruits, often yielding 25 tons or more per acre. It keeps well and although grown primarily as succulent feed for cattle, it is also suitable for table use. On the other hand, Marblehead squash vines succumb very readily to squash bug attack.

Squash bugs were found in outbreak numbers near Prosser, in the lower part of Yakima Valley in 1939. The following year preliminary observations on biology, host relationship and control were started at the Irrigation Branch Experiment Station near Prosser.

BIOLOGY.—Cage tests at Prosser have shown that one adult squash bug feeding for a single day is capable of causing the death of a seedling Marblehead squash plant. The plants wither and die ten days to two weeks after the attack. Older plants are able to withstand squash bug attack longer. This ability to survive is roughtly in proportion to the age of the

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[2] The author acknowledges the help of Mr. F. A. Kirsch, Temporary assistant, Agricultural Experiment Station, summer 1941 and 1942. Now Assistant County Agent, Agricultural Extension Service, Yakima, Washington, and Mr. N. S. Wilson Temporary assistant, Agricultural Experiment Station, summer 1940. Now Associate Entomologist, U.S.D.A., B.E.P.Q., Pear Psylla Project, Spokane, Washington.

plant. However, no Marblehead plant, regardless of size or age, can be said to be immune from squash bug attack and subsequent death. Plants with runners 15 feet long and fruit 10 inches in diameter have succumbed to squash bug attack even though control measures had been used.

The squash bug has two generations in the Yakima Valley where a 160 to 190 day growing season exists. The bugs emerge from hibernation early in June and immediately seek squash plants. It is the feeding of overwintered adults on the stems of the seedling plants at ground level that accounts for most of the destruction of plants. Apparently first generation nymphs that develop during July are not so injurious because they feed mostly on the leaves. Summer generation adults appear in August, followed shortly by second generation nymphs; both feed largely on the foliage. Squash plants are large enough to support quite a sizeable population at that time without a great amount of injury. Hibernating adults develop late in September and in October and, with the late, second generation nymphs, may literally cover the mature squash plants and fruits before flying to hibernation.

INJURY.—The injury caused by the squash bug in Utah has been termed "anasa wilt of cucurbits" by Robinson & Richards (1931). Knowlton (1935) refers to this injury as do Hoerner (1938) in Colorado and Manis & Shull (1941) in Idaho. Injury in Washington agrees with these descriptions. Similar injury results in Oregon too. Apparently in the west, squash bug injury is much more severe than reported from the east by Beard (1940).

This injury is distinct from western yellow blight. Furthermore, the striped cucumber beetle, *Diabrotica vittata* Fabr., the squash vine borer, *Melittia satyriniformis* Hbn., and the wilt disease caused by *Bacillus tracheiphilus*, all serious pests of squash in other sections, have not been found in eastern Washington. The disorder is caused by squash bug feeding alone, and not by a combination of ills as suggested by Beard (1940). Plants caged in the field and so protected from squash bugs develop normally (Fig. 1). Why squash bug feeding causes the plant to wilt and die so rapidly has never been determined. J. D. Menzies, Assistant Plant Pathologist located at Prosser, was not able to obtain pathogenic material from the bug or dying plants. Numerous published accounts agree on this point and contain many conjectures as to the causal agent. Pack (1930) showed that the ability of the squash bug to cause wilting and dying of squash plants through its feeding was carried from one generation to the next through the eggs. The most logical conclusion is that the bug injects a toxic substance while feeding, and that substance upsets the circulatory system of the plant, but this has yet to be proved experimentally.

HOST PLANTS.—With the advent of the squash bug, field trials of various squashes and pumpkins have been conducted by W. J. Clore, Horticulturist at Prosser Station, to find a substitute for Marble head. From these, it is concluded that Kentucky Field Pumpkin, of the varieties capable of withstanding curly top disease, survives squash bug attack best and that Marblehead succumbs most easily. Kentucky Field Pumpkin is not immune, but squash bugs attack other varieties as long as available and only feed on Kentucky Field Pumpkin as a last resort. Summer squashes survive squash bug attack (as well as curly top) to a considerable extent, but this is largely through escape since the plants develop so rapidly that they are nearly mature by the time the bugs appear. Watermelons and cantaloupes may also be attacked if favored varieties of squash are not available. The growing of melons has been an industry of about 2000 acres in the Yakima Valley in the past.

CONTROL.—Control of squash bug at present centers around the protection of seedlings from overwintered bugs. Control of summer broods of squash bug on the older plants is a less critical, contingent problem. Pyrethrum dust[1] (Hoerner 1938) and activated nicotine dust[2] (Lamiman 1933) applied 20–40 pounds per acre will destroy as many as 90 per cent of the bugs on the plants. Squash bugs fly from field to field all summer however, and these along

[1] First reported as effective against squash bug by Hoerner in Colorado. Inert dust coated with an extract of pyrethrum and diluted with more dust so as to contain 0.2 per cent pyrethrins.

[2] First recommended for use by Lamiman against the grape leafhopper in California. The experimental work of Dr. Lamiman and Mr. K. D. J. Gillies of the Tobacco By-Products & Chemical Corporation, Inc. upon which this recommendation was based was never published. The dust was made as follows: Nicotine sulfate (40 per cent), ten pounds; hydrated lime, 80 pounds; sodium carbonate (soda ash), 10 pounds. The dust was used immediately after mixing, since gaseous nicotine is released very rapidly.

with the survivors necessitated such frequent (sometimes even every other day) application as to make dusting economically impractical except under conditions like 1942 when the value of squash skyrocketed to $120 per ton due to scarcity on the market. Calcium cyanide dust as used by Pack (1930) and subsequently by Moore (1936) against squash bugs, is as effective as the other materials when used as frequently and heavily, but it stunts the plants in addition to being costly. Squash bug dusting may contribute to lack of pollination through destruction of bees and other flower-visiting insects, but squash pollination is extremely variable even under normal conditions. Preliminary tests with other materials have failed to yield any promising leads. The problem is to find a material that will maintain protection over a prolonged period.

Other control measures (hand picking, placing shingles under the plants, and caging plants) are used in small plantings. If, in searching for bugs, the plants are rolled around after runners develop, the runners do not take root, the plants remain small, and a poor set of fruit results. Trap crops of Marblehead and summer squash have been used successfully to protect cantaloupes.

During the 1943 season, squash bug damage was not as severe as in previous years. Even Marblehead squash was produced with the aid of moderate control efforts in various parts of the Yakima Valley. From all indications, the bug infestation is losing its outbreak proportions. Perhaps the squash bug is being brought into equilibrium with its new environment. A great deal of this effect is due to a cold winter, a delayed cool growing season, and the drastic curtailment of squash production prompted by losses from squash bug in past seasons.

The squash bug parasite *Trichopoda pennipes* Fabr. of the eastern states, was introduced into the Yakima Valley during 1943 under the auspices of the Washington Agricultural Experiment Station in the hope that it would become another natural factor checking squash bug depredations. The Foreign Parasite Introduction Laboratory of the Bureau of Entomology and Plant Quarantine at Hoboken, New Jersey, collected and shipped the material. Mr. C. W. Getzendaner, at the Potato Flea Beetle Laboratory of the Bureau at Union Gap, handled the rearing and liberation. The parasites completed two generations in the field during the summer, but it remains to be seen if they can overwinter in Washington and actually prove to be effective against the squash bug.

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PEST CONTROL OPERATORS MEET AT PURDUE

The 9th Annual Pest Control Operators' Conference was held at Purdue University, Lafayette, Indiana, January 15–19, with a record registration of 184. Twenty-three states and Canada were represented, with Florida and Texas the southern range and Colorado the distant state to the west. Of the total registration 64 were in attendance for the first time. Forty entomologists, chemists, pest control operators, army officers and representatives of the chemical industries were on the program. Among the entomologists who took part were Ed M. Searls, G. C. Decker, B. G. Berger, Major Franklin Sherman III, J. J. Davis, G. E. Lehker, H. O. Deay, George L. Hockenyos, J. Carl Dawson, Lieut. L. C. Truman, and G. E. Gould. J. J. Davis was in charge of the conference.

SCIENTIFIC NOTES

Survival of Anopheline Larvae and Pupae in Muck

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North Carolina State Board of Health, Raleigh[1]

On several occasions during 1944 relatively high adult malaria mosquito counts, not immediately explainable by larval data, occurred on malaria control programs in certain coastal areas of North Carolina. In an effort to determine the cause for these augmentations of adult counts, intensive larval inspections were carried out in suspected breeding areas. In the course of such investigations, the writers became aware of an anopheline larval adaptation which could partially explain the puzzling adult counts. This adaptation was expanded into a so-called "muck theory of anopheline larval—pupal survival." Two brief experiments and general observations were carried out to test this theory. Unfortunately, the work was not initiated until early September so that several planned experiments could not be conducted. However, the results from the work accomplished are of sufficient promise to warrant a preliminary report in the hope that the data may be of value to other malaria control investigators.

The coastal areas of North Carolina in the vicinity of Jacksonville, New Bern, and Elizabeth City are subject to wind tides which cause the creeks and rivers to inundate adjacent acreages for periods lasting from 1 to 20 days. There is no periodicity of these tides, areas may be flooded several times during one week, even though the length of any one inundation may be less than 24 hours. Anopheline breeding often occurs in these flooded areas, and frequently it is necessary to apply a larvicide. In any given locality the mosquito breeding depends upon the duration of the wind tide and rainfall.

Anopheles quadrimaculatus Say, in these coastal areas, shows a wide divergence of breeding habitats varying from those generally considered favored (grassy pools, lake margins, etc.) to habitats that from appearance do not seem suitable (non-vegetated muddy ditches, hog wallows, non-vegetated central areas of large creeks, heavily shaded swamps, hoof-prints, etc.).

At New Bern an anopheline house in a river edge swamp showed a count of 14 male and 3 female *Anopheles quadrimaculatus* in mid August. Adjacent to the house ran a nearly overflowing ditch filled with floatage and debris and having a muck bottom. At 9 A.M. on August 18 this ditch appeared as described above, no larval tests being made; at 2:30 P.M. the same ditch was completely drained except for scattered trickles and small, shallow pockets. A larval investigation at this time showed only two small anophelines. This situation plus several subsequent similar incidents gave rise to the opinion that possibly anopheline larvae and pupae could submerge themselves in the muck when the tide receded and later, when the tide rose again, come to the surface and continue their development.

At Elizabeth City two experiments were devised to test the possibilities of the "muck theory." Anopheline larvae and pupae were collected, together with a supply of mud and water. The latter was placed in a 10-quart bucket and the anopheline larvae and pupae added to the surface water where they were permitted to move about for a few minutes. The water was then carefully drawn off with a pipette and toilet tissue until the surface was reduced to the consistency of a moderately thick mud. Following this the bucket was placed in the open where it was exposed to direct sunlight for approximately 2 hours each day. The results are given in table 1.

Table 1.—Survival of anopheline larvae and pupae in muck.

Specimens Used	No. Used	No. Surviving
	29 hours	
2nd stage larvae	3	1
3rd stage larvae	3	2
4th stage larvae	9	7
Pupae	4	4
	48 hours	
3rd stage larvae	2	0
4th stage larvae	14	3
Pupae	4	4

At the conclusion of the 29-hour test the mud was of the consistency of putty. When water was applied, however, all surviving larvae and pupae promptly arose to the surface. Within twelve hours three adults (two male and one female *Anopheles quadrimaculatus*) emerged from three pupae, one of the males appearing one hour after water was applied. Two of the fourth stage larvae pupated and produced adults of *A. quadrimaculatus*. All other surviving specimens died later.

At the end of the 48-hour test the mud was still uniformly moist but tended to be somewhat thick and sticky; it approached the crumbly stage, not remaining in one piece when squeezed into a ball. From the four pupae emerged 3 female *Anopheles quadrimaculatus* and 1 male *A. punctipennis*. Two of the surviving larvae died, the third pupated and then died.

In both tests the pupae seemed better fitted for survival. Larval survival appeared to be reduced by lengthening the drying-out period.

These experiments although brief in character do show that it is possible under test conditions for anopheline larvae and pupae to survive in muck for a limited period. How long such survival is possible for the various stages must be worked out, preferably under field conditions. A test pool made with mud banks for this purpose at Elizabeth City was unfortunately obliterated by heavy rains.

Although no field experiments were performed, one observation at Elizabeth City showed that larval survival in muck does occur under natural conditions. On September 6 inspection of a ditch serving to carry waste water from a house revealed an apparently dry ditch, the bottom being a slimy muck. Two days later the same ditch contained a shallow layer of soapy waste water which yielded 44 third and fourth stage *Anopheles quadrimaculatus* larvae and numerous culicine fourth-stage larvae and pupae. It is obvious that these larvae and pupae must have been present in the ditch on the first inspection. The only portion of the ditch not observed during the initial inspection was a section 8 feet long under a low wooden bridge. It is possible that all the larvae and pupae were under the bridge

[1] The authors are all Entomologists, Malaria Investigation and Control Unit.

at that time but the distribution of the anophelines would indicate otherwise. All "quads" were collected approximately 30 feet from the side of the bridge farthest from the source of waste water and none were observed in the dense culture of culicines (immediately adjacent to the bridge) nor were any of the latter taken with the anophelines. If the two types of larvae had been under the bridge, in the same puddle or in separate ones, it seems logical that when the waste water rose in the ditch the two types would have been interspersed. As observations revealed, however, there was at least a 20-foot space between the two groups of larvae. This fact would indicate that the anopheline larvae on September 6 were in the muck. In this incident the periodic release of waste water into the ditch created a situation that is roughly comparable to those found in areas subject to wind tides.

It is evident that whenever this type of larval survival occurs it would be necessary to vary the control measures, particularly the larviciding. Ditch construction to concentrate the tidal water and allow its most rapid elimination would be advisable. Ditches which show larval survival in the muck would require larviciding whenever they contained sufficient water to bring the anophelines out of the muck provided at least 7 days had elapsed between consecutive oil treatments.

Anopheles walkeri in Diurnal Shelters in Massachusetts

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Adults of *Anopheles walkeri* Theobald are rarely encountered in diurnal shelters of the type commonly used for measuring densities of the closely related *A. quadrimaculatus* Say. Published records of the collection of *A. walkeri* from their daytime resting places are few and are limited to the South.

Komp (1926) stated that he had collected *Anopheles walkeri* along with *A. quadrimaculatus* and *A. crucians* Wiedemann in barns, under houses, and in similar shelters at Crowley, Louisiana. Bradley (1936) reported small numbers of *A. walkeri* resting in the daytime under overhanging grass around the margins of a marsh in Florida. Johnson (1936) collected 2510 anophelines from cow sheds, stables, chicken houses, under houses, tree trunks, and in dense woods at Reelfoot Lake, Tennessee without finding a single specimen of *A. walkeri*, although the species was unusually common in collections from a nearby light trap. Bang, Quinby, and Simpson (1943) found that at Reelfoot Lake, Tennessee, *A. walkeri* displayed a marked preference for very humid situations. These writers found the favorite resting place of *A. walkeri* to be the dark shaded bases of mature cut-grass, *Zizaniopsis miliacea*. They were most commonly found resting just above the water surface, only occasionally above moist mud, and rarely in drier places. These investigators reported that when *A. walkeri* was found in cow sheds, it was, in all instances, found within a few inches of the moist floor or in the dark moist corners of the feeding troughs.

During August and September of 1943, while making anopheline surveys in eastern Massachusetts, the writer noticed small numbers of *Anopheles walkeri* in diurnal shelters. The species was observed in ten such stations in three localities, namely Ayer, Taunton and Waltham. At Ayer, 50 station inspections were made from which 304 anophelines were taken. Of this number, 12 or 3.95 per cent were *A. walkeri*. Forty collections from adult stations were made at Taunton and 368 anophelines were taken. Five of these, or 1.36 per cent, were *A. walkeri*. Seventeen stations were inspected at Waltham and 424 anophelines were collected. Only one of this number, or 0.24 per cent, was *A. walkeri*. A total of 18 adults of *A. walkeri* were taken in the three areas and the maximum collection for a single station was seven. A small number of larval collections were also made in each area (24 in all) but none of the 124 large anophelines taken was *A. walkeri*.

Table 1.—Anopheline collections from diurnal shelters in which *Anopheles walkeri* was found.

Locality and Date	No. and Type of Station	Number of Female *Anopheles* Taken		
		walkeri	*quadrimaculatus*	*punctipennis*
Ayer				
Aug. 27	No. 10, cow stable	1	2	3
Sept. 23	No. 7, cow stable	1	2	0
Sept. 24	No. 13, hog stable	1	0	1
Sept. 24	No. 14, cow stable	7	0	2
Sept. 24	No. 16, cow and horse stable	2	0	1
Taunton				
Aug. 24	No. 15, cow stable	1	61	0
Sept. 16	No. 15, cow stable	1	10	2
Sept. 16	No. 17, cow and horse stable	1	0	0
Sept. 16	No. 19, cow stable	1	2	0
Sept. 17	No. 7, cow stable	1	2	0
Waltham				
Sept. 21	No. 16, cow stable	1	6	1
Total		18	85	10

The data relative to the collections of *Anopheles walkeri* are summarized in Table 1. Only female anophelines are listed in this table since no males of *A. walkeri* were taken. Other anophelines were present in all but one of the stations from which *A. walkeri* was collected and these too were females, with the exception of a single male of *A. quadrimaculatus* which was found in Station No. 7 at Taunton. It will be noted that all specimens of *A. walkeri* taken were found in animal shelters, usually cow stables. They were found in fairly dry situations on the ceilings and upper walls and not in the moister places near the floor. Other types of stations which were also inspected were culverts, hollow trees, outbuildings, under houses, and under bridges. Such stations often yielded considerable numbers of anophelines but none of these were *A. walkeri*.—12-5-40.

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A United States Record for *Culex interrogator*

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During the fall and winter of 1943, larvae of *Culex interrogator* D. & K. were included in routine collections of mosquitoes made in connection with Malaria Control in War Areas operations in Cameron and Hidalgo Counties, Texas. The species was first collected from two stations near the city of Harlingen by Mr. D. C. Pfeifer and was later taken from two stations near the city of Edinburg by Mr. T. T. Loudos. First collection was made on October 4 and the species was still being submitted in small numbers as late as early January, 1944.

As far as the writers can determine, this species has not previously been reported from the United States. Its range was given by Dyar (1928) as Mexico and Panama.

The larvae were in each case taken from irrigation seepage areas along with those of *Culex coronator* Beyer, *Culex nigripalpus* Theob., *Culex erratious* D. & K., *Uranotaenia lowii* Theob., *Anopheles pseudopunctipennis* Theob., *Anopheles albimanus* Wied., and perhaps other species. The water was shallow and vegetation consisted mostly of grasses. At least some of these areas dry up intermittently and the water at one station had a distinct sulphurous odor. Dyar (1928) describes the breeding places of this species as "very dirty ground pools and treeholes."

Larvae of *Culex interrogator* from the Rio Grande Valley conform closely to the description given by Dyar (1928) with the exception that in our specimens the air-tube is somewhat more than three times as long as wide whereas Dyar states that the air-tube is short and slightly less than three times as long as wide. The most distinctive character of these larvae is the presence of long heavy, spine-like pecten teeth toward the apical portion of the air tube.

A reared female of this species was found to agree very closely with Dyar's description. In this connection it might be stated that the species of small *Culex* (*Culex*) and *Culex* (*Melanoconion*) are difficult to distinguish and the adults of *Culex interrogator* are easily overlooked in collections made by hand or light trap.

A single reared male was examined by Mr. W. H. W. Komp who found the terminalia to be identical with Panama material of the same species. —11-20-44.

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Anopheles walkeri in South Carolina

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In recent literature (Middlekauf & Carpenter 1944) the occurrence of *Anopheles walkeri* Theobald in South Carolina has been mentioned as probable, and it is not listed from this state by King & Bradley (1942) in their review of the distribution of nearctic *Anopheles*. By hearsay, the breeding of this species has been known to occur in the old rice field marshes at the mouth of the Savannah River in Jasper County, South Carolina. The senior author took larvae from a growth of *Zizaniopsis miliacea* Doell. & Aschers on the Savannah River Refuge of the Fish and Wildlife Service in 1939 and 1940 but none of these were preserved. In addition, James H. Birnie of the State Agricultural and Mechanical College at Orangeburg, South Carolina, stated in correspondence that he took this species in Orangeburg County near Branchville in June and July of 1940.

In a recent note Bradley *et al.* (1944) list two records of this species (larvae) obtained from the South Carolina State Board of Health. Both of these apparently refer to the Branchville collections mentioned above, although the Orangeburg locality is in error.

In an effort to document the occurrence of this species in the Savannah River marshes a visit was made to the locality on May 10, 1944. No larvae were taken but a one-hour biting collection resulted in the capture of 16 female *Anopheles walkeri* along with two *A. quadrimaculatus* and one *A. crucians*. Subsequently on May 12, 1944, about 18 additional specimens were taken, some of which fed and oviposited in the laboratory. On the latter date a greater proportion of *A. quadrimaculatus* and *A. crucians* were taken.

Two additional collecting trips were made on May 26 and July 14 respectively. Very few *Anopheles quadrimaculatus* and *A. crucians* were taken on these two trips. On the first of the trips about 180 females of *A. walkeri* were taken. The elapsed time was 3 hours. Illumination was furnished by the dome-light of the car with an occasional very brief use of the headlights.

The catch on July 14 was over 600 during a slightly shorter period of time. On this trip the dome-light was not used and a very bright light from a gasoline lantern was substituted. This increased illumination may have been responsible for the larger catch. Other influencing factors may have been the greater population occurring later in the season or more favorable meteorological conditions.

Of these specimens two have been deposited in the U. S. National Museum; two in the collection of the Fourth Service Command, Army of the United States; two in the collection of Malaria Control in War Areas, Atlanta, Georgia; two in the collection of Clemson College; and the remaining preserved specimens in the collection of Malaria Investigations, U. S. Public Health Service. Other specimens may be distributed later.—11-20-44.

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Factors Affecting Survival of Plum Curculio in Peach Orchards[1]

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The survival of plum curculio in peach orchards is known to be affected by many factors including number of broods, frequency of crop failure, availability of shelter for overwintering adults, prevalence of infested trees near the orchards, temperature-moisture relationships at certain critical periods during the season and intensity of sunshine on drop fruits containing eggs and young larvae. Timely cultivation destroys some larvae and pupae. A greater use of arsenicals on apple than on peach has brought about lower curculio populations in apple orchards than in peach orchards especially in areas where codling moth is the predominant apple insect. The mortality of curculio adults due to mild arsenical schedules on peach seldom equals the total mortality of eggs, larvae and pupae that is due to natural causes.

Small numbers of second brood larvae have been found in a few varieties of peach and plum in southern Pennsylvania during August each year since 1942. Here, many of the annually producing peach orchards border woodland and uncultivated land. The shelter afforded by woodlands, in addition to sheltering plum curculio, has often protected trees from winter freezes. Some of the older orchards have had one crop failure in more than 20 years.

In recent years, weather conditions have been alternately favorable and unfavorable for the development of large curculio populations in southern Pennsylvania orchards. A slight downward trend in curculio injury occurred from 1938 to 1942 attributable partly to improved timing of spray applications. High soil moisture and many cloudy days favored an increase in curculio populations during 1942. During 1943, fruit injury reached a high point for recent years and averaged approximately 20 to 50 per cent from inner to outer rows of 15 peach orchards counted before thinning and fruit drop occurred. A high level of soil moisture prevailing at the time larvae entered soil in 1942 and 1943 probably induced the shallow pupation observed at ½ to 2 inches below the soil surface. Drought conditions and high temperatures developing immediately after the peak of larval entry into soil caused considerable mortality of larvae in 1943. Sizeable curculio infestations were only encountered beside woodlands and uncultivated land in 1944. Drought conditions prevailing at the time larvae entered into soil during 1944 were accompanied by pupation mostly 2½ to 4 inches below the surface of soil and some pupae were found six inches below the surface.

Information on the survival of plum curculio has been sought by the writer to determine whether certain manipulations might be used by orchardists to avoid a curculio problem. Data and observations

Table 1.—The survival of plum curculio at Arendtsville, Pennsylvania, under varied conditions during 1944.

1000 fruits in each medium listed below	Summer Emergence of Adults				Adults per 1000 Injured Fruits
	Began	25%	75%	Complete	
Influence of soil type: (Equal numbers of fruits in sun and in partial shade)					
	July	July	July	July	
on sand	8	13	14	29	274
on penn gravel loam	5	9	13	30	244
on penn silt loam	6	11	14	25	173
Influence of cultural treatments: (Equal numbers of fruits in sun and in partial shade over penn gravel loam)					
on surface of dry grass mulch	8	12	17	29	97
on surface of dry grass mulch—watered equivalent to 1 in. rain on June 1	6	10	14	22	181
on slaked surface crust	5	9	13	30	244
on loose soil surface	6	10	14	29	297
buried 1.5 in. below the surface	6	10	14	29	252
buried 0.75 in. below the surface	6	10	13	20	333
on surface stirred to depth of 2.5 in. June 25 and July 5 (3000 fruits)	5	10	13	30	208
Influence of sunshine:					
on 3 soil types—unshaded (1500 fruits)	6	10	15	27	73
on penn gravel loam—unshaded	6	8	12	21	74
on grass mulch over penn gravel loam—unshaded	8	9	11	24	54
buried 0.75–1.5 in. in penn gravel loam—unshaded	6	9	13	20	158
on 3 soil types—in partial shade (1500 fruits)	5	11	14	30	387
on penn gravel loam—in partial shade	5	10	13	30	467
on grass mulch over penn gravel loam—in partial shade	6	12	15	29	224
buried 0.75–1.5 in. in penn gravel loam in partial shade	6	11	14	29	427

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in the orchards had indicated some of the possibilities but more exact quantitative data were sought by another method in 1944.

METHOD.—Samples of 500 injured fruits were assembled from fruits knocked from trees on June 1, 1944, seven days after the beginning of fruit drop. Each sample was composed of 20 fruits from each of 25 trees. All samples were assembled from the same trees. Approximately 90 per cent of the egg-laying on these trees had occurred from shucksplit on May 12 to May 24. The larvae were reared from 2 samples in the insectary, 782 emerging from 1000 fruits between June 2 and June 24. Twenty four samples were placed in concrete frames measuring 20″×30″ and previously filled with soils to a depth of 5 inches, above a base of Penn gravel loam. Lath frames with 1 inch openings between strips were used to provide partial shade over 12 frames. The remaining frames were not shaded. Screen covers were fitted inside of the tops of frames on June 20. The emergence of adults occurred from July 5 to July 30 and was recorded daily. The frames, screen covers and lath shades used in the study are illustrated in Fig. 1.

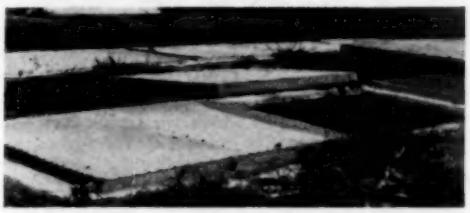

FIG. 1.—Concrete frames, screen covers and lath shades used in the study of plum curculio emergence under varied soil conditions at Arendtsville, Pa.

WEATHER.—The rainfall during June and July was 44 per cent of normal. Precipitation in June totalled 2.19 inches with measurable amounts of rain falling on 12 days. Precipitation in July was 1.43 inches but no rain fell from June 30 to July 12. The mean temperature for June and July was 0.6° F. above normal. Maximum air temperatures for June and July were 95 and 97° respectively. Mean maximum air temperatures for June and July were 83 and 89° F. respectively. Maximum temperatures of 90° F. or above were recorded on 24 days during June and July. The maximum temperature recorded at the surface of soil in the sun was 120° F.

RESULTS.—Soil type and location of pupation affected the time of emergence, the 50 per cent point of emergency varying as much as 5 days. Emergence was delayed longest from sand in sun and from soil under dry mulch beneath fruits. Light, late rains induced sharper peaks of emergence from sand than from other soils.

The results of treatments are given in table 1. On the soil types studied, survival was lowest from the densest soil. The survival, as determined by emergence of adults, was greater from fruits on a loose soil surface than from fruits on a slaked surface crust. The use of mulch beneath fruits, equivalent to 2½ tons of dry grass per acre, induced shallower pupation and lower survival both in sunlight and in partial shade than other cultural treatments. However, the addition of water on mulch equivalent to 1 inch rainfall increased the survival. The results of cultivation to a depth of 2½ inches suggest that cultivation is not highly effective where deep pupation occurs. The survival of curculios from fruits in sunlight was much lower than from fruits in partial shade but the burial of fruits in sunlight more than doubled the survival.—11-30-44.

Ground Cover Sprays to Kill Insects and Weeds in Peach Orchards[1]

HAROLD M. STEINER,[2] *The Pennsylvania State College*

Alderfer & Shaulis (1943) have pointed to the desirability of maintaining surface litter in the peach orchard to reduce water and soil losses during heavy rains.

The use of herbicides in place of cultivation to reduce weed and cover crop competition at times when most of the nutrients and soil moisture can be used by the trees offers a method of accumulating a desirable surface litter. An herbicide that sterilizes the soil or one that prevents resumption of growth by suitable covers would not answer the need. One that fails to kill certain insects can serve to drive them to the trees in much the same manner as a delayed cultivation.

Increasing numbers of miscellaneous peach insects and particularly grasshoppers have been noted in many partly cultivated orchards of southern Pennsylvania. This, accompanied by frequent requests for information on measures of prevention of injury to foliage and fruits, has stimulated the writer to engage in this study.

Tests of some insecticides having herbicidal properties were conducted at the Arendtsville Laboratory and at the Battlefield Peach Orchard, Gettysburg, Pa., during 1944 to determine some of the limitations that might be encountered in future study. Laboratory studies were conducted on insects collected from nearby orchards. Herbicides were first applied to short strips of weeds in the orchard to eliminate unpromising materials. Final trials were made with two spray mixtures, each applied between 8 rows of Hale and Elberta peach trees.

The trees in the orchard were 3 years old. The planting square was 15 by 15 feet. Middle strips approximately 9 feet wide between rows had been undisturbed by cultivation for 3 years before spraying. They contained a variety of annual and perennial weeds common to this region. Six-foot strips embracing the tree rows had received 3 cultivations in 1942, 2 in 1943 and one in 1944, the last on May 15 before sprays were applied in August. Grasshoppers were the predominant insects in the orchard during August, 1944.

METHOD OF APPLICATION.—A spray boom and a drag sheet were essential to keep caustic sprays from tree foliage and to reduce the quantities of materials needed for high kills. The boom used in applying test sprays was made of 1 inch pipe 8 feet long fitted with 14 nozzles with .047-inch apertures. The nozzles were directed backward and downward serving to spray the front sides of weeds bent forward by a drag sheet that coated the back sides

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[2] The writer is indebted to Professor Vernon Haber for identification of grasshopper species.

with spray in passing. The drag sheet was a painter's drop cloth measuring 12 by 15 feet. It was tacked to boards casing two sides of the boom. The boards served to protect the nozzles against striking the ground. The boom was attached to the sprayer by short lengths of spray hose. It was suspended by light ropes from the rear of a truck-mounted sprayer so that nozzles hung 4 to 5 inches above ground while spraying between small trees but it could be dragged beside the truck by an arm attachment while spraying beneath branches of larger trees.

Test sprays were applied by two men, one driving the truck and the other guiding the drag sheet away from tree trunks and around the ends of rows. Sprays were applied at 500 pounds pressure, approximately 10 gallons per minute and at 250 gallons per acre of sprayed surface being used.

MATERIALS.—In initial trials on test strips of weeds, two mixtures were outstanding in effectiveness at low concentrations. These were a powder containing 40 per cent dinitro-ortho-cyclo-hexyl phenol often referred to as DNOCHP and a test material, *Code No. G-410* of Dow Chemical Co., containing 1 pound of pentachlorphenol per quart in a carrier prepared for use with oil sprays. These two materials were used with a paraffin base oil, *Gulf Oil Co. #372*, tank mixed with *B-1956*, a proprietary spreader-emulsifier produced by Rohm and Haas Co. In orchard trials, *G-410* was used at 2 quarts per 100 gallons of spray containing 2 gals. petroleum oil and 2 oz. *B-1956*. Similarly, the 40 per cent DNOCHP powder was used at 2 pounds per 100 gallons of spray containing 2 gallons petroleum oil and 2 oz. *B-1956*. Each of these mixtures was used at half strength against caged insects in the tests reported here.

EFFECT ON WEEDS.—Applications of each of the spray mixtures were highly effective in killing the top growth of all weeds encountered in the orchard on August 15. The weeds were killed above the surface of the ground within 48 hours after spraying. Roman ragweed and wild lettuce predominated at the time of spraying. Other common plants on which top growth was killed included goldenrod, smartweed, red clover, white clover, dandelion, hawkweed, broad and narrow leaved plantains, crab-grass, foxtail, blue grass, poison ivy, Canada thistle and sheep sorrel. A deficit in seasonal rainfall checked the growth of weeds in unsprayed strips. The recovery of weeds as indicated by new top growth was noted within 10 days after the sprays were applied. Plants that showed greatest recovery after 3 weeks included blue grass, dandelion, red clover and sheep sorrel. Dandelion, plantains and sheep sorrel had made a mat over the sprayed soil within 5 weeks after treatment. Germinating seeds and seedlings of wild carrot, blue grass and broad leaved plantain covered all bare spaces of soil within 7 weeks after spraying. The weight of green growth was measured from cuttings of plants at the soil line from six 2-ft. squares 1, 3, 5 and 7 weeks after treatment. The gram weight of green growth on 12 square feet of unsprayed surface totaled 732, 714, 828 and 900 grams on these dates compared with an average of 24, 66, 390 and 936 grams for the same dates on the two spray treatments.

The writer has used DNOCHP-oil sprays for several seasons to reduce the growth of weeds and poison ivy under apple trees where records of drop fruits were to be taken. The spray has been least effective against poison ivy in dense shade. It is therefore suggested that similar sprays be applied only on sunshiny days.

EFFECTS ON SOIL MOISTURE.—The precipitation for the 5-week period preceding spray applications totalled 2.16 inches. The growth of weeds was retarded by drought at the time of spraying. The precipitation during 3 weeks following treatment totalled 1.3 inches. At this time, surface soil and soil to a depth of 2 inches was noticeably moist on sprayed plats, whereas unsprayed plats were very dry. The precipitation in 7 weeks following treatment totalled 5.0 inches and soil moisture in the sprayed plats was noticeably higher than in the unsprayed plats although recovery of weeds on sprayed plats had equalled the weight on unsprayed plats. The growth of weeds and grasses returning on the sprayed plats first suggested a stimulating action of the chemicals but the evidence at hand indicates that the lush growth was due to more favorable soil moisture levels on the sprayed plats.

EFFECTS ON INSECTS.—Insects collected in nearby orchards were caged in 10 inch wire screen cages with open bottoms over blue grass sod at the laboratory. The insecticidal tests were made at convenient times from August 5 to September 8 at temperatures ranging from 65° F. to 95° F. The two spray mixtures previously mentioned were used at one-half the concentration used in herbicidal trials. They were applied with a knapsack sprayer. Ten insects of each species were used in each test. Grasshopper adults of two species, *Melanoplus differentialis* Thos. and *Melanoplus femur rubrum* DeGeer, tarnished plant bugs, buffalo treehopper, Japanese beetle and plum curculio were all killed where the test sprays were applied directly to the insects. Grasshoppers succumbed within 2 hours after direct treatment while mortality of other species occurred within 12 hours. There was no mortality of insects in unsprayed cages within this interval. Additional tests were conducted wherein each of the insect species was placed in cages over freshly sprayed grass but was not hit by spray. The insects on the sides of cages were then urged to enter the sprayed grass by brushing the sides of cages. Again the mortality of grasshoppers, plant bugs and treehoppers over both spray mixtures was complete. Japanese beetles and plum curculio adults were killed after entering freshly sprayed grass wet with DNOCHP-oil but not by pentachlorphenol-oil. Grasshoppers of both species placed over grass that had dried for 2 hours succumbed to each of the spray mixtures within 24 hours. In the orchard, following application of herbicides, dead and dying grasshoppers and tarnished plant bugs were found on weeds and on the ground within a few minutes after treatment.

EFFECTS ON TREES.—Growth of trees, as measured by the increase in trunk diameters of 80 trees per treatment between 2 and 7 weeks after treatment, was not affected by the sprays at herbicidal strength. The per cent increase in trunk diameters during this 5 week period was 5.5, 5.4 and 5.6 respectively for the unsprayed, DNOCHP and *G-412* treatments. Ten gallons of each spray mixture was drained from the sprayer on the surface of soil near the base of each of 4 trees. No evidences of injury occurred from this treatment except where the liquid touched the trunk of one tree treated with pentachlorphenol. However, 30 gallons of each material applied in the same manner caused wilting within 24 hours and eventual death of the tree.

The dosage of materials needed to kill insects and weeds by the use of a pressure sprayer, ground boom and drag sheet was less than 3 qts. of dilute spray per 100 square feet, an amount believed to be in-

sufficient to cause injury to the tree if the materials are kept from the trunk and foliage.

The cost of application of materials sufficient to kill many insects and to retard growth of weeds would not greatly exceed the cost of double discing. —11-30-44.

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Effectiveness of *Macrocentrus ancylivorus*. Reared from Strawberry Leaf Roller in Parasitizing Oriental Fruit Moth

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For many years adults of *Macrocentrus ancylivorus* reared from the strawberry leaf roller have been used in liberations against the oriental fruit moth. Although such liberations have generally given satisfactory results, it has been suspected that such parasites might be less effective against the oriental fruit moth than parasites reared from the fruit moth.

This possibility was tested in 1943. Two small peach trees were enclosed in each of six cages. During the following 6 weeks all infested twigs were cut and removed as they appeared. When the natural infestations of the oriental fruit moth and its parasites were thus eliminated, the cages were stocked with equal numbers of oriental fruit moth adults. A week later a total of five *Macrocentrus ancylivorus* females reared from field-collected larvae of the strawberry leaf roller were placed in two of the cages, two females in one cage and three in the other, while five such parasites emerging from field-collected larvae of the oriental fruit moth were similarly placed in two other cages. All these females were probably mated, as they had previously been confined with males and males were introduced into the cages with them. The infested twigs were cut from the trees in all cages 7 and 11 days after the parasite releases and the insects were reared from them.

The data on recovery show that from the cages stocked with *Macrocentrus ancylivorus* obtained from strawberry leaf roller a total of 555 insects emerged, of which 62, or 11.2 per cent, were *M. ancylivorus*. From the cages stocked with *M. ancylivorus* obtained from oriental fruit moth a total of 681 insects emerged, of which 62, or 9.1 per cent, were *M. ancylivorus*. From the two cages that received no parasites, 626 insects emerged, none being *M. ancylivorus*.

A similar experiment was conducted in 1942. The trees used in this test were rather small, the interval between the introduction of moths and the introduction of parasites was too long, and only a small number of insects were reared. The results, therefore, were inconclusive, although the trend was much the same as in 1943.

The data indicate that *Macrocentrus ancylivorus* originating from the strawberry leaf roller attacks the oriental fruit moth as well as does *M. ancylivorus* originating from the oriental fruit moth.—3-13-44.

Sources of Overwintering *Macrocentrus ancylivorus*

H. W. ALLEN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

Available evidence indicates that the population of the parasite *Macrocentrus ancylivorus* Rohwer which winters over successfully in bearing peach orchards of the principal commercial varieties is relatively low, yet in many districts the species reappears in large numbers in such orchards during the presence of the first brood of its host, the oriental fruit moth, *Grapholitha molesta* (Busck). In the case of tree fruits, this important parasite attacks the twig-infesting host larvae very freely but is unable to reach a high percentage of them in the fruit. Very few oriental fruit moth larvae are present in peach twigs later than midsummer (except in young, nonbearing peach orchards) and the parasite thus has difficulty in maintaining itself in most peach orchards in late summer and fall.

There are several reasons for considering that the spring increase in the abundance of *Macrocentrus* is due to migration of adult parasites into the orchards from nearby sources more heavily stocked with overwintering *M. ancylivorus*. It is important to know what these sources are, since orchards in a locality where restocking occurs are likely to have increased parasitization and reduced fruit injury.

Several hosts of *Macrocentrus ancylivorus*, other than the oriental fruit moth, have been reported in literature. To be of importance in restocking peach orchards with that parasite in the spring a host must occur in considerable abundance in districts where peaches are grown, and in locations not far distant from peaches. Their overwintering broods must sustain a relatively large population of this parasite.

Until recently no alternate host had been found that fulfilled these requirements in respect to peach orchards in southern New Jersey. The ragweed borer, *Epiblema strenuana* Walk., is abundant and well distributed in respect to peach orchards, but the population of *Macrocentrus ancylivorus* overwintering in it has always been found to be very low. Concentrated populations of *M. ancylivorus* overwintering in the strawberry leaf roller, *Ancylis comptana fragariae* (Walsh & Riley), in cultivated strawberry are of common occurrence, but the area devoted to cultivated strawberry is relatively small, and many peach orchards having a large spring population of *M. ancylivorus* are located several miles from the nearest cultivated strawberry.

In the fall of 1943 it was found that a number of plants other than cultivated strawberry are hosts for relatively large overwintering populations of the strawberry leaf roller in southern New Jersey, that these plants, collectively, are widely distributed over the terrain devoted to peach culture, and that the leaf rollers developing on these plants are heavily parasitized by *Macrocentrus ancylivorus*. Several species of wild and cultivated blackberries and dewberries and the cultivated red respberry all supported moderate to heavy infestations of overwintering strawberry leaf rollers,[1] which were in most cases extensively parasitized by *M. ancylivorus*. The wild blackberries and dewberries are abundant and widely distributed, occurring in patches of various sizes in waste fields, along the borders of highways,

[1] A total of 91 specimens reared from the above listed plants have been examined by Mr. Carl Heinrich, and all were identified as *Ancylis comptana fragariae* (Walsh & Riley).

railroads, farm roads, ditches, woodlots, pastures, and shallow ravines. A detailed survey of four square miles in 40-acre sections, in a peach-growing district near Evesboro, N. J., showed that wild blackberry occurred in 59 of the 64 sections, at distances of less than a quarter of a mile from every peach orchard, and on all sides of most orchards. In contrast to the abundance of wild blackberries was a scarcity of cultivated strawberry, only one small patch being found in this area.

The estimated numbers of overwintering strawberry leaf roller larvae in 3 patches of dewberry ranged from 530 to 3330 and averaged 2050 per thousand square feet. In 3 patches of wild blackberry it ranged from 530 to 1750 and averaged 1000 per thousand square feet. This was much greater than the overwintering population of the strawberry leaf roller in cultivated strawberry in the same district, which was estimated at only 50 per thousand square feet in 1943, and 98 in 1941.

Macrocentrus ancylivorus was recovered from overwintering strawberry leaf rollers in wild blackberry from 11 of 16 locations sampled, and from 2 of 3 locations of dewberry sampled. The average rates of parasitization by *M. ancylivorus* ranged from 6 to 16 per cent for blackberry, and were 21.3 per cent in dewberry.

Cultivated blackberry and cultivated red raspberry are not grown extensively in the area surveyed, but in the Hammonton, N. J., district plantings are abundant, and the acreage of the two berries, considered collectively, appears greatly to exceed that of cultivated strawberry. Many of these plantings in that area are near peach, and the infestation of overwintering strawberry leaf roller found in them was nearly as heavy as that occurring in wild blackberry. The degree of parasitization by *Macrocentrus ancylivorus* found in the cultivated berries was even greater than that found in the wild blackberries, being 32 per cent in blackberry and 42 per cent in red raspberry.

Wild blackcap raspberry, swamp rose, wild strawberry, and cinquefoil were lightly to moderately infested by the strawberry leaf roller, but *Macrocentrus ancylivorus* was absent or very scarce. The distribution of these plant hosts was, in general, less favorable than that of the wild blackberry and dewberry.—11-27-44.

A Chemical Method of Freeing Cocoons of *Macrocentrus ancylivorus* from Tuber Moth Cocoons

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The Division of Beneficial Insect Investigations of the University of California has been engaged in a program of mass production of *Macrocentrus ancylivorus* Rohwer for the past season utilizing the potato tuber moth *Gnorimoschema operculella* (Zell.) as a laboratory host (Flanders 1943).

Under the methods described by Finney *et al.* (1944) the parasitized host *Gnorimoschema operculella* affixes itself to a silt covered cardboard in process of construction of its cocoon. Within the cocoons so formed the unparasitized potato tuber moth chrysalid or the cocoon of *Macrocentrus ancylivorus* develop. The cardboards are held until eclosion of the unparasitized moth chrysalids at which time the cardboard sheets with the remaining parasite cocoons are sent to the field where emergence takes place. This method of liberation of the parasite pupae in the field is desirable in contrast to shipment of the adult parasites, since it extends the period during which adults are present at the infested locale. It has been recognized by the previously mentioned workers that a method of separation of parasite cocoons and the unparasitized host chrysalids prior to the period of potato tuber moth eclosion would be desirable, in order to permit more complete separation of parasite cocoons from contaminating potato tuber moths at time of shipment. It would also lengthen the period during which parasite cocoons could be shipped to points of liberation without danger of emergence en route.

The following procedure has been used in freeing parasite cocoons and potato tuber moth chrysalids from the enclosing cocoons of the potato tuber moth. The cocooning material is scraped from the cardboard to which it adheres. It is then washed of host cocooning silk and extraneous cocooning material by immersion in dilute sodium hypochlorite solution. As the solution is slowly stirred, the silk is dissolved and the free moth crysalids and free parasite cocoons float to the surface of the chemical wash, while the undissolved silt sinks to the bottom of the container. The cocoons and chrysalids are removed from the chlorinated wash water, rinsed, mechanically separated, and prepared for shipment.

The eclosion of neither the parasite nor the potato tuber moth seemed to be affected in preliminary tests in which a 1.3 per cent by weight sodium hypochlorite solution was used.

It is probable that this procedure may permit modifications in future mass production and handling of *Macrocentrus ancylivorus*.

In addition to the above use, the property of sodium hypochlorite to dissolve insect silk suggests its use as a contact spray adjunct in control of pests which are protected by silken webs.—12-14-44.

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Separating *Macrocentrus* Cocoons from Tuber Moth Pupae

GLENN L. FINNEY, *University of California Citrus Experiment Station, Riverside*

Following the discovery by Bartlett & Martin (*vide supra*) that *Clorox* (sodium hypochlorite) provided a means for eliminating tuber worm cocoons in mass production work, there remained the necessity of separating the tuber worm pupae from the *Macrocentrus* cocoons so as to obtain stocks of the latter for shipment. This has been successfully accomplished without apparent injury to either host or parasite by the use of 95 per cent alcohol. Because of their comparatively high specific gravity the tuber worm pupae sink readily. Within 30 seconds the floating *Macrocentrus* cocoons can be skimmed from the surface of the alcohol.—12-21-44.

Seed-Corn Maggots as Pests of Coniferous Seedlings in Western Washington[1]

E. P. BREAKEY, C. J. GOULD, and C. E. REYNOLDS[2]

In July, 1944, it was learned that an infestation of maggots was doing considerable damage to coniferous seedlings in the forest nursery of the West Coast Lumbermen's Association at Nisqually, Washington. Douglas fir seedlings were the most severely injured though Spruce seedlings were also attacked. It was estimated that close to twenty per cent of the fir seedlings were killed by the maggots. Of perhaps equal importance, though more difficult to estimate, is the extent of the injury suffered by seedlings which continued to live though greatly retarded in growth and physically stunted. It has been estimated that as much as forty to fifty per cent of the last three seedings were lost because of injury from this pest. (Fig. 1)

FIG. 1.—Injury to fir seedlings by seed-corn maggot. Note uneven growth of surviving plants.

The nurserymen had attributed this injury to such possible causal agents as sun scald, damping-off fungi, etc. In fact, the most recent approach to a solution of the problem was based on the assumption that the loss was due to damping-off fungi. While taking data to determine the effectiveness of the various fungicidal treatments, maggots were found attacking the young seedlings. Moreover, the maggots were present in sufficient numbers to justify accusing them of being the cause of the damage noted.

Flies issued from the plant beds late in July and early in August in considerable numbers, indicating that a generation of the insect was reaching maturity at that time. Specimens of the fly were sent to Dr. H. C. Huckett, Entomologist with the New York Agricultural Experiment Station, for identification. Dr. Huckett assigned the specimens to the species, *Hylemyia cilicrura* (Rond.), the seed-corn maggot.

All fungicidal treatments were ineffective against the insect with the exceptions of chloropicrin and DD (a mixture of dichloropropylene and dichloropropane). Chloropicrin, it will be noted, has gained rather general recognition as a soil fumigant while DD is a promising new material. The seed was planted on June 25, a week after the beds had been treated with the chemicals. In fact, the fumes of chloropicrin were still coming from the soil in appreciable amounts, which may have a bearing on the results. Each material was used at four concentrations, and two replications were made of each concentration.

Counts were made and data taken on July 17. The chloropicrin was the most effective of the two treatments, reducing the per cent fatally injured or dead plants from a possible 18.4 per cent to 7.5 per cent as compared with a reduction by the DD from a possible 21.3 per cent to 10.4 per cent. It was also noted that there was no appreciable difference in the effectiveness of the four concentrations used, and that the bed which had been treated with chloropicrin was outstanding in the uniformity and vigor of the young fir seedlings. (Fig. 2)

FIG. 2.—Injury to fir seedlings by seed-corn maggot. Bed on left treated with chloropicrin a short time before seeding.

It was noted that maggots were present in considerable numbers on July 17 and 19. At this time the maggots were working at a shallow depth and individual maggots were apparently going from one seedling to another. Some maggots were found between the epidermis and the steele, their presence indicated by a large bulge or swelling in the stem of the seedling. The epidermis and cortex of many seedlings had been lacerated or shredded by the insects. Puparia were found at a depth of six to seven inches on July 21 when it was noted that most of the maggots had ceased feeding. Adults were emerging in numbers on July 28 and continued to do so for a period of several days.—1-9-44.

[1] Published as Scientific Paper No. 633, College of Agriculture and Agricultural Experiment Stations, State College of Washington.

[2] Research Entomologist and Research Plant Pathologist, Washington Agricultural Experiment Stations respectively, and Forester, West Coast Lumbermen's Association.

Phyllocoptes gracilis, a Pest of Red Raspberry in the Puyallup Valley[1]

E. P. BREAKEY[2]

Early in August, 1944, a number of branches of the Lloyd George variety of the red raspberry were brought to the Western Washington Experiment Station. Each of these branches bore a number of fruits that had failed to develop normally. These fruits were hardened and somewhat misshapen, and

[1] Published as Scientific Paper No. 632, College of Agriculture and Agricultural Experiment Stations, State College of Washington.

[2] Research Entomologist, Washington Agricultural Experiment Stations.

superficially resembled the fruits of the blackberry when they have been injured by the mite, *Eriophyes essigi* Hassan, the cause of the "redberry disease."

When these fruits were examined under the microscope they were found to be infested with an Eriophyid mite. Both mites and infested fruits were sent to Mr. H. H. Keifer, Entomologist with the California Department of Agriculture, under date of August 10, together with a letter of explanation and a request that he identify the species causing the condition noted.

Mr. Keifer replied on August 14, and identified the mites as *Phyllocoptes gracilis* (Nal.). He also stated that "*Phyllocoptes gracilis* (Nal.) has been known as a pest of certain species of *Rubus* for a good many years. However, *Eriphyes essigi* Hassan overshadows it, at least on the west coast. Down here in California *gracilis* seems to be rare or actually absent."

It has been estimated that fifty per cent of the plants in this field of the Lloyd George variety of red raspberry bore fruits which were obviously affected in the manner described. It was difficult, if not impossible, however, to estimate the percentage of damaged fruit, but the damage was appreciable. The Tahoma and Washington varieties on this property were apparently unaffected. Other growers have reported the condition as affecting the Washington variety, though apparently to a lesser extent.—1-9-44.

DDT as a Control for Cherry Fruit Fly[1]

S. C. JONES, *Oregon Experiment Station, Corvallis*

Preliminary experiments were undertaken in the laboratory and in the field with DDT for cherry fruit fly, *Rhagoletis cingulata*, control. DDT preparations tested in the laboratory were the following: 2 per cent and 3 per cent DDT combined with electric sulfur and talc as a dust; 5 per cent DDT in oil, at concentrations of 1 pint, 1 quart, and 2 quarts to 100 gallons of spray; 20 per cent DDT combined with a spreader used at concentrations of one and two pounds to 100 gallons of spray. Both fruit and foliage were sprayed or dusted with the above materials. Ten flies of even age were placed in the test cages immediately after spraying or dusting. The flies were observed at eight-hour intervals until 50 per cent mortality occurred. A 10 per cent sucrose solution was placed in each of the cages to prevent mortality from starvation.

The lethal action of all the DDT preparations was slow, although some of the flies showed typical DDT symptoms within an hour after they were placed in the cages. The 2 per cent and 3 per cent DDT dusts killed 50 per cent of the flies in 80 and 88 hours respectively. Liquid sprays required 88 hours or longer to produce 50 per cent mortality. Fifty per cent or more of the flies were still alive in the check cages 384 hours after the tests were begun.

Two field plots received one application of 2 per cent and 3 per cent dust respectively, combined with 50 per cent electric sulfur and talc. One plot which was interplanted with prune trees and surrounded by a severely infested orchard was thoroughly dusted with a 2 per cent DDT dust 6 days after the first flies began to emerge. Interplanted trees, as well as a one-row buffer, were dusted in addition to the cherry trees. The cherry trees were mixed sweet varieties including Bing, Lambert, and Royal Anne cherries. A total of 2476 cherries were examined from this plot which showed an infestation of 3356 larvae. A second small orchard was dusted with 3 per cent DDT combined with 50 per cent electric sulfur and talc. This orchard was severely infested in 1943 but was isolated from other orchards. It included the same varieties of sweet cherries listed above. All the trees were dusted with a power duster eight days after the first flies began to emerge. A total of 3452 cherries were taken at random from the dusted trees and examined for cherry fruit fly larvae and 1089 larvae were taken from these cherries

The results show that one application of DDT when used at the above concentrations was not effective against the cherry fruit fly.—11-22-44.

[1] Published as Technical Paper Number 448 with the approval of the Director of the Oregon Agricultural Experiment Station, contribution of the Department of Entomology.

Ground Treatment with DDT to Control Pear Thrips in Soil Under Prune Trees[1]

S. C. JONES, *Oregon Experiment Station, Corvallis*

A proprietary material known as "*Gesapon*" *No. 18*,[2] containing 5 per cent DDT in solution, was tested as a soil insecticide for the control of adult pear thrips *Taeniothrips inconsequens* Uzel. The material was received too late for application at the beginning of the thrips emergence season. The experimental applications were made near the peak of emergence.

Three series of experimental tests were set up. One series of plots was treated with *Gesapon* at the rate of 1 gallon of the concentrate in 100 gallons of solution. A second series was treated with two quarts of the concentrate in 100 gallons, and a third with one quart in 100 gallons. The first two series were replicated three times and the third two times. Adjacent check plots were set up for comparison with each treated plot and a count of the emerging thrips was made from standard thrips cages which were placed over each plot immediately after the applications were made. One gallon of the diluted material was applied to each plot. The plots were 3 by 3 feet in size.

A total of 1, 1 and no thrips emerged in cages placed over plots treated with *Gesapon No. 18* and used at concentrations of one gallon, 2 quarts and 1 quart to 100 gallons of spray. The total emergence for a like number of untreated cages adjacent to the treated cages was 561, 541 and 14 thrips respectively.

Unfortunately, the *Gesapon* was received too late for conducting a larger series of plots or for using larger plots. Since no thrips emerged in plots treated at the lowest concentration, the concentration could probably have been reduced further. The amount of the diluted material per plot might also have been reduced.—12-28-44.

[1] Published as Technical Paper Number 449 with the approval of the Director of the Oregon Agricultural Experiment Station. Contribution of the Department of Entomology.

[2] Prepared by the Geigy Company.

Terpin Diacetate as an Activator for Pyrethrum[1]

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Investigations with derivatives of turpentine and pine oil have resulted in the discovery of several chemical compounds of considerable insecticidal value. Two of these, *D.H.S. Activator*[3] (ethylene glycol ether of pinene) and *Thanite*[4] (a terpene thiocyano ester) have been developed for commercial use. They are now employed extensively in the manufacture of liquid, spray-type, household insecticides. This paper deals with terpin diacetate, which was found to be an effective activator for pyrethrum.

EXPERIMENTAL PROCEDURE.—The flies (*Musca domestica* L.), used in this study, were bred in a room maintained at temperatures ranging from 78 to 82 degrees F. and at between 50 and 70 per cent relative humidity.

Materials were prepared for testing by Hercules Powder Company chemists and the writer. *Deobase*,[1] a petroleum distillate, water-white in color, practically odorless, and of (30/32)/100 Saybolt Viscosity, served as the base oil in all formulae.

The series of tests included sprays containing 25, 50 and 100 mg. pyrethrins per 100 cc., both without terpin diacetate and with 2.5, 5 and 10 per cent of terpin diacetate added. They were conducted in accordance with the small-group, Peet-Grady procedure.

The method of evaluating liquid, spray-type, household insecticides, in conjunction with the Official Test Insecticide (O.T.I.) designated by the National Association of Insecticide and Disinfectant Manufacturers, was followed in analyzing all data.

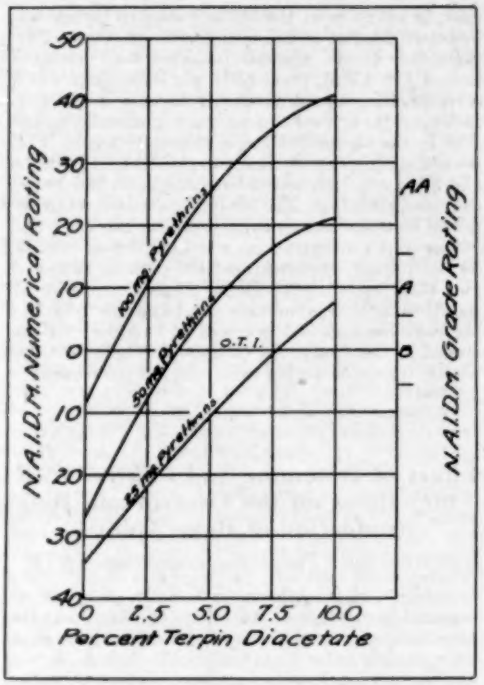

FIG. 1.—Activation of 25, 50 and 100 mg. pyrethrins by terpin diacetate in *Deobase*.

DISCUSSION OF RESULTS.—The data, summarized in table 1 and presented graphically in figure 1, show

[1] Study conducted under Hercules Powder Company Naval Stores Research Fellowship, and results released as Publication 196 and Scientific Article 122 of the Department of Entomology, Delaware Agricultural Experiment Station, with the approval of both the Director of the Station and the supporting Company.

[2] Hercules Research Fellow; on leave of absence as Major, SnC., AUS.

[3] Reg. U. S. Pat. Office, by Hercules Powder Company.

[4] Secured from L. Sonneborn Sons, Inc.

Table 1.—Summary of the toxicity of 25, 50 and 100 mg. pyrethrins per 100 cc. with terpin diacetate in *Deobase* to three-day-old flies.[1]

Mg. Pyrethrins per 100 cc.	Per Cent Terpin Diacetate	Number of Tests	Pyrethrum-Terpin Diacetate: Per cent Down in 10 Minutes	Pyrethrum-Terpin Diacetate: Per cent Dead in 24 Hours	O.T.I.: Per cent Down in 10 Minutes	O.T.I.: Per cent Dead in 24 Hours	N.A.I.D.M. Rating: Grade	N.A.I.D.M. Rating: Numerical
25	0.0	10	78.3	12.0	98.2	46.6	Below B	−34.6
	2.5	10	91.4	22.6	98.0	47.6	Below B	−25.0
	5.0	10	96.4	37.2	98.0	46.5	Below B	− 9.3
	10.0	10	97.7	55.1	97.9	46.9	A	+ 8.2
50	0.0	10	88.6	15.6	96.5	42.8	Below B	−27.2
	2.5	10	93.7	31.8	96.4	42.3	Below B	−10.5
	5.0	10	96.9	49.9	95.7	42.0	A	+ 7.9
	10.0	10	98.1	62.9	96.1	41.2	AA	+21.7
100	0.0	10	95.7	32.7	97.0	42.0	Below B	− 9.3
	2.5	10	97.3	49.8	97.4	40.5	A	+ 9.3
	5.0	10	97.8	63.5	96.6	37.7	AA	+25.8
	10.0	10	98.9	81.0	97.3	40.2	AA	+40.8

Tests conducted according to the small-group, Peet-Grady procedure.

that, in every case, the toxicity of pyrethrum was increased by the addition of terpin diacetate. Furthermore, as the amount included was increased from 2.5 to 5 and, then, to 10 per cent, there was a corresponding and pronounced increase in toxicity. However, these increases were not in direct relationship to the amount of terpin diacetate added. Proportionaly greater increases were obtained with 2.5 and 5 per cent concentrations than with the 10 per cent concentration. The average increases, as determined from the numerical ratings, for the 2.5, 5 and 10 per cent concentrations when employed with 25, 50 and 100 mg. pyrethrins per 100 cc. were 15.0, 31.8 and 47.3, respectively. The average increase for all pyrethrum-terpin diacetate combinations was 13.4 per cent for each 2.5 per cent of this material included in the spray. All of these combinations displayed the quick-acting toxic effect of pyrethrum.—12-22-44.

Effect of Rotenone and *Velsicol (AR-60)* Dusts on the Control and Reproduction of Bean Aphids[1]

YUN-PEI SUN,[2] *Cornell University, Ithaca, N. Y.*

Toxicity of insecticides is usually expressed in terms of percentage of mortality. In some cases the expression of mortality may be insufficient to show the complete value of an insecticide. Aphids, for example, may continue to reproduce very rapidly after treatment before being killed by the insecticide. In such a case the aphids population may not decline to a great extent even though a large proportion of the aphids have been affected and eventually killed by the treatment. Such a possibility has been observed from laboratory tests made on bean aphids, *Aphis rumicis* L., using rotenone-[3] *Velsicol*-[4] talc[5] dusts.

[1] Research project supported by the Velsicol Corporation.
[2] Acknowledgement is made to Dr. Roy Hansberry for valuable suggestions and to Dr. L. B. Norton for the determination of rotenone content in Derris root powder.
[3] Derris root powder containing 3.1% rotenone.
[4] *Velsicol (AR-60)*, methylnaphthalenes, manufactured by Velsicol Corporation.
[5] Eastern magnesia talc (*Ewtco 23*).

Bean aphids were reared on nasturtium in the greenhouse and dusting experiments were carried out in the laboratory at temperatures ranging from 22° to 26° C. Twenty-five mature wingless females and a nasturtium leaf were placed on two layers of wetted paper towel in an open dish (4″ diameter and 1.5″ deep). Then dust was tapped down from a small vial covered with a layer of fine bolting silk so that the insecticide would fall down as fine dust. By careful dusting and by rotating the position of the dish the results were fairly uniform. It was found that the average deposit of 10 replicates was 0.64 mg/sq. cm. After dusting, dishes were each covered with two layers of cheesecloth and piled up one over another. Twenty-four hours after dusting the mature aphids unable to walk were counted as dead; the young aphids exhibiting movement of legs or antennae were considered alive. In table 1 each entry represents the average of at least eight replicates, each consisting of 25 mature wingless females.

It is shown in Series A (Table 1) that large numbers of young were produced by the treated mature females. Reproduction gradually decreased with each increment of rotenone in the dust mixture. However, the number of young aphids produced by the mature females treated with low concentrations of rotenone (0.023 to 0.078 per cent) was greater than the number of young produced by those treated with talc (control). In general, reproduction was high in the groups treated with rotenone-talc dusts during the 24 hour period, in spite of the high mortality of the mature females. In Series B and C, with 1 per cent and 2 per cent of *Velsicol* respectively, the initial increase in the number of young aphids due to the addition of rotenone was also observed. It should also be emphasized here that a higher proportion of young aphids were alive in the groups treated with rotenone-talc dusts than those treated with dusts containing *Velsicol*. In the right hand vertical column of table 1 where rotenone is absent, the mortality increased from 4.7 per cent to 100 per cent as the amount of *Velsicol* increased. On the other hand, the number of young aphids decreased from 321 to 14. The same trend also occurred in other experiments in which the rotenone percentage remained constant while the percentage of *Velsicol* varied.

From the above analysis of results it is apparent that rotenone-talc dust has a stimulating effect on

Table 1.—Average mortality and reproduction per 100 mature wingless females of bean aphids, *Aphis rumicis* L., dusted with various concentrations of *Velsicol (AR-60)* and rotenone dusts, (24 hours after dusting).

	Per Cent Rotenone in the Dusts						
	0.47	0.31	0.15	0.078	0.039	0.023	0
A. Dusts without *Velsicol (AR-60)*							
Per cent mortality of mature wingless females	100	100	100	100	99.7	80.8	4.7
Young produced	102	163	273	342	378	420	321
Estimated living young aphids	a few	a few	some	many	most	most	all
B. Dusts with 1 per cent of *Velsicol (AR-60)* and various amounts of rotenone							
Per cent mortality of mature wingless females		100	100	100	100	99.7	44.3
Young produced		42	126	132	150	168	26
Estimated living young aphids		none	a few	a few	some	many	many
C. Dusts with 2 per cent of *Velsicol (AR-60)* and various amounts of rotenone							
Per cent mortality of mature wingless females			100	100	100	100	100
Young produced			17	6	59	30	14
Estimated living young aphids			none	none	none	none	a few

the reproduction of bean aphids while *Velsicol*-talc dust tends to inhibit their reproduction. Preliminary experiments with *Velsicol*-rotenone-talc dusts used against cabbage aphid, *Brevicoryne brassicae* (L.), and pea aphid, *Macrosiphum pisi* (Kltb.), gave similar results.

The ineffective and unreliable results in the field control of pea aphids (Walker & Anderson 1939, 1940; Shropshire 1941 p. 12) and spinach aphids, *Myzus persicae* (Sulzer), (Walker & Anderson 1943) with rotenone products may have some connection with the stimulating effect of rotenone on the reproduction of the aphids. It is interesting to read Walker & Anderson's (1939, p. 504) statement: "The dusts (rotenone) checked the (pea) aphids temporarily and killed many of them but the surviving aphids reproduced so rapidly after treatment that they soon killed the growing tips of the plants." In such case, stimulation of reproduction by rotenone dusts is suspected by the writer to have had some connection with the rapid increase in population. As indicated by the present data, the *Velsicol*-talc dust or *Velsicol*-rotenone-talc dust may be preferable to rotenone-talc dust in terms of potential population.

SUMMARY.—In the laboratory tests of insecticides it was found that rotenone-talc dusts stimulate the reproduction of bean aphids, *Aphis rumicis* L., while *Velsicol* (*AR-60*)-talc dusts tend to inhibit their reproduction. This finding may explain the ineffective and unreliable results in the field control of some species of aphids with rotenone products.—1-15-44.

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Preliminary Tests with Sabadilla

E. H. FISHER and W. W. STANLEY[1]

During the month of September, 1944, the writers had the opportunity of conducting a few tests with sabadilla to determine its effect on the following insects: Mexican bean beetle, *Epilachna varivestis* Muls.; corn earworm, *Heliothis armigera* (Hbn.); green clover worm, *Platythpena scabra* (F.); German cockroach, *Blatella germanica* (L.); and harlequin bug, *Murgantia histrionica* (Hahn). The tests were carried out at the Tennessee Agricultural Experiment Station, at Knoxville.

The material used is known as *McConnon Sabadilla Concentrate No. 1*, which contains 50 per cent ground sabadilla seed treated with alkali in accordance with the technique developed by Dr. T. C. Allen and associates at the University of Wisconsin. The sabadilla was prepared by McConnon and Co., Winona, Minnesota, by the grinding of seeds of the plant *Schoenocaulon officinale* Schlect & Champ., which comes from Caracas, Venezuela. Only 93.5 per cent of this concentrate passed through a 200-mesh screen.

For use, the *Sabadilla Concentrate No. 1* was diluted with *Pyrax ABB* to percentages ranging from 2.5 to 20 per cent of pure sabadilla. The samples were weighed out on a chemical balance, placed in a quart-size paper carton, and shaken by hand for a few minutes.

Tests were usually run with 250-mg. or 500-mg. samples that were blown into a dusting chamber and allowed to settle for 5 minutes. These amounts gave deposits which were calculated to range from 40 to 80 pounds of dust per acre.

After dusting, the harlequin bug and German cockroach were placed in small wooden cages free from insecticide, and observed. The leaf-eating insects were placed in clean tin salve boxes, with food either dusted or not dusted according to particular test being conducted.

HARLEQUIN BUG.—Tests using a total of 175 individuals, and 500-mg. samples of sabadilla, ranging through 2.5 per cent, 5 per cent, 10 per cent, and 20 per cent, showed that the harlequin bug is readily susceptible to this material. At 20 per cent strength, all adults were knocked down in 5 minutes, and within 15 hours all were killed. Smaller concentrations took longer for the knockdown and failed to produce a complete kill. Sabadilla of 2.5 per cent concentration required 45 minutes for a 100 per cent adult knockdown, and gave only a 73 per cent kill in 72 hours, although 7 per cent of the remaining bugs were moribund.

Nymphs were more resistant, showing only 80 per cent knockdown in 30 minutes with 20 per cent sabadilla. At the end of 72 hours, 93 per cent were dead and the remainder were moribund. There was no knockdown with 2.5 per cent at 30 minutes; at end of 72 hours, the kill was 40 per cent with 33 per cent moribund.

On the basis of these tests it appears that from 5 per cent to 10 per cent sabadilla may give effective control of this pest, since results with these concentrations fell between those with the 2.5 per cent and 20 per cent concentrations. On adults, 250-mg. samples were a little less effective than 500-mg. samples. The smaller samples were not tried on nymphs.

On October 4, a few hills of green sprouting broccoli were found heavily infested with adult harliquin bugs. They were dusted with 10 per cent sabadilla, 10 per cent alkali, 40 per cent sulfur, and 40 per cent *Pyrax*, at a rate of about 35 pounds per acre. Within a few minutes the harlequin bugs came tumbling out. Some of them managed to fly off, but many remained on the ground and soon became moribund. Other species of insects were noted to be leaving the treated plants. The test was repeated when the plants were wet with dew. The action of the sabadilla under the moist conditions was much quicker and a good kill was obtained.

GREEN CLOVER WORM.—Tests with green clover worm included only 25 larvae, and the use of 250 mg. of sabadilla at 10 per cent and 20 per cent strengths in the dust chamber. These larvae are quite active and when stimulated they flip about; but one hour after being dusted with 20 per cent sabadilla they were unable to move. Within 18 hours, however, nearly all had recovered from the paralysis. During a 4-day test they did not eat the dusted bean foliage, and very little kill was obtained. In another

[1] Co-authorship: E. H. Fisher, Entomologist, Stokely Foods, Inc., Madison, Wisconsin. W. W. Stanley, Associate Entomologist, Tenn. Agr. Exp. Sta.

test, larvae remained in cages with dusted food for 3 days before taking food, and all were dead on the sixth day. Tests with 10 per cent sabadilla showed that while it did not have as much contact effect as 20 per cent, it did prevent the larvae from eating.

Undusted larvae on clean foliage consume the foliage readily and survive.

MEXICAN BEAN BEETLE.—The tests with Mexican bean beetle involved the use of a total of 700 individuals, including larvae and adults. The data obtained from the use of 250 mg. show that 20 per cent sabadilla was the most effective strength. Treating adults and larvae and then placing them on clean leaves resulted in slight kills; reversing the test—placing undusted insects on treated leaves—gave a 72 per cent kill of larvae and 20 per cent kill of adults in three days. It was noted that the insects did not eat much of the treated foliage; the larvae ate 5 per cent and the adults practically none.

Sabadilla was most effective when insects and bean leaves were both dusted. Kill of larvae and adults with 20 per cent sabadilla was 74 per cent and 80 per cent respectively in 72 hours. The material had more knockdown effect on the adults; the 20 per cent material in one test showing 90 per cent moribund at 24 hours.

Bean foliage sprayed with a solution of 1 to 340 sabadilla was offered to larvae. At end of 3 days they had eaten only 30 per cent of the foliage, and 10 per cent of them were dead. Clean foliage as a rule is all eaten in a day or two.

CORN EARWORM.—Tests with corn earworm included only 65 larvae, and the use of only 10 per cent and 20 per cent sabadilla in 250-mg. samples. The larvae used generally were more than half grown, and this probably accounts for the small kill obtained. Sabadilla did not knock out the corn earworm as it did the green clover worm. It had no great effect on the larvae, although it did cause them to refuse to eat beans for about 36 to 48 hours. When they were sufficiently starved they ate the dusted food, but suffered only slight mortality. The 10 per cent strength appeared to be as effective as the 20 per cent.

GERMAN COCKROACH.—Tests with German cockroaches showed that sabadilla is effective against this pest also, if high concentrations and 500 mg. samples are used. The few tests showed that 50 per cent sabadilla gave 100 per cent knockdown in 10 minutes and 100 per cent kill in about 40 hours. During the 40 hours required to kill, the roaches were moribund, lying on their backs, and able to kick or move their antennae only spasmodically. With 20 per cent sabadilla the knockdown was much slower; also the kill was delayed. Tests with 10 per cent sabadilla showed very little toxic effect, there being only 10 per cent knockdown in 24 hours; however, when sulfur was used as a carrier the knockdown was increased to 90 per cent in 24 hours.

MISCELLANEOUS TESTS.—Tobacco leaves were dusted and placed in cages with tobacco worms and grasshoppers. Neither of these pests would eat the treated leaves.

SUMMARY.—The results of the tests show that sabadilla is highly toxic to certain insects, such as the harlequin bug, by its contact effect. Sabadilla was observed to be very repellent to both adults and larval stages of certain chewing insects. The material did not seem to have much toxicity as a stomach poison. However, under field conditions it will perhaps kill small larvae by contact and further affect the insects by repellency. Another noticeable feature of sabadilla was its ability to paralyze, or cause moribundity. This was specially noted with harlequin bug and German cockroaches.

The tests indicated good to perfect control of the insects with sabadilla when prevention of damage as affected by the combination of kill, moribundity, and repellency is considered.

Addition of sulfur to sabadilla enchanced control in all cases in which it was tested.

Data presented here, together with findings concerning control of *Empoasca fabae* (Harris) on snap beans, to be published soon by workers in Wisconsin, indicate that sabadilla may be used to control all the main bean pests, control of which has commonly required three different insecticides.—11-9-44.

The Larva of *Agonopteryx lecontella*

S. W. FROST, *Pennsylvania State College*

In 1929 the writer collected a single larva rolling the leaf of false indigo, *Baptisia tinctoria* (L.), at Arendtsville, Pa. The adult was reared and determined by J. F. G. Clarke[1] as *Agonopteryx lecontella* (Clem.). It happens to be the only specimen in the National Museum, thus, a few notes on the larva of this apparently uncommon species seems worthwhile and may aid others in obtaining specimens.

The larva was taken on June 22, 1929 at which time it was nearly fully grown. It was green including the head and thorax. The prothoracic shield bore a dark spot on each side and the tubercles of the body were shiny black. The larva pupated on June 26 and the adult emerged on July 4th.—12-9-44.

[1] Clarke, J. F. G. 1941. Proc. U. S. Nat. Mus. 3107, Vol 90: 95.

Some Ectoparasites, Excluding Ixodoidea, of Delaware Mammals[1]

DONALD MACCREARY,[2] *University of Delaware, Newark*

Incidental to an investigation of the "Distribution and Host Relationships of *Dermacentor variabilis* (Say) in Delaware," a considerable number of records of other ectoparasites were secured.[3] Since few of these insects and mites have been reported from the state, it seemed advisable to compile a list (Table 1) from the data obtained during this period (1939–41). Insects of domestic animals are excluded, since the occurrence of such pests as cattle and hog lice, the fleas of cats and dogs, poultry insects and mites and similar common forms is so well-known

[1] Information secured under Purnell Project E-12, and published with the approval of the Director of the Delaware Agricultural Experiment Station as Publication 197 and Scientific Article 123 of the Department of Entomology.

The following ticks have been collected in the State: *Ixodes dentatus* Neumann, *I. cookei* Packard, *I. marxi* Banks, *Haemaphysalis leporis palustris* Packard, *Rhipicephalus sanguineus* Lat., *Amblyomma maculatum* Koch, *A. americanum* Linn. and *Dermacentor variabilis* (Say).

[2] Associate Entomologist; on leave of absence as Lt. Commander, U.S.N.R.

[3] The Acarina were determined by Dr. H. E. Ewing and the Coleoptera, by Dr. W. S. Fisher of the U. S. Bureau of Entomology and Plant Quarantine. The Siphonaptera and Anoplura were identified by Robert Traub and E. J. Gerberg, respectively, (at the time) of Cornell University. Prof. C. O. Houghton of the University of Delaware determined certain of the small animals.

that the recording of such species does not appear to be warranted.

With a few exceptions, most of the small animals were taken alive under natural conditions in fields and forests. No collections were made around the Port of Wilmington, thereby precluding the possibility of taking the Oriental rat flea which may be present at that point. It is recognized that further examinations would result, undoubtedly, in adding practically all of the wild mammals in the state to the following list of hosts and would disclose, as well, a still greater number of ectoparasites.

The following is a list of the ectoparasites and the hosts of each as recorded in this study:

ACARINA

Laelaps microti (Ewing)
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse

Laelaps spiniger Ewing & Stover
- *Ondatra zibethica zibethica* (L.), Muskrat

Laelaps spp.
- *Blarina brevicauda* (Say), Short-tailed shrew
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Pitymys pinetorum pinetorum* (Lec.), Pine mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Atricholaelaps glasgowi (Ewing)
- *Blarina brevicauda* (Say), Short-tailed shrew
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Pitymys pinetorum pinetorum* (Lec.), Pine mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Euhaemogamasus liponyssoides (Ewing)
- *Blarina brevicauda* (Say), Short-tailed shrew
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse

Euhaemogamasus microti (Ewing)
- *Pitymys pinetorum pinetorum* (Lec.), Pine mouse

Liponyssus bacoti Hirst
- *Rattus norvegicus* (Erxleben), Common rat

Trombicula whartoni Ing.
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Pitymys pinetorum pinetorum* (Lec.), Pine mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Neoschongastia brevipes (Ewing)
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Eutrombicula tropica (Ewing)
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse

ANOPLURA

Hoplopleura acanthopus (Burm.)
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse
- *Mus musculus* L., House mouse

HEMIPTERA

Cimex pilosellus Horv.
- *Myotis lucifugus lucifugus* (Lec.), Brown bat

COLEOPTERA.

1. In the exact interpretation of the term, these species are not ectoparasites. However, since they were collected in the fur of the respective hosts, it seemed desirable to list them here.

Leptinus testaceus Mull.
- *Blarina brevicauda* (Say), Short-tailed shrew

Corticaria elongata Gyll.
- *Sylvilagus floridanus malluras* Thomas, Cottontail rabbit

SIPHONAPTERA

Cediopsylla simplex (Baker)
- *Marmota monax monax* (L.), Woodchuck

Ctenophthalmus pseudagyrites Baker
- *Blarina brevicauda* (Say), Short-tailed shrew
- *Microtis pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Pitymys pinetorum pinetorum* (Lec.), Pine mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse
- *Sylvilagus floridanus malluras* Thomas, Cottontail rabbit

Oropsylla arctomys (Baker)
- *Vulpes fulva fulva* Desmarest, Red fox
- *Marmota monax monax* (L.), Woodchuck

Orchopeas wickhami Baker
- *Sciurus hudsonicus loquax* Bangs, Red squirrel

Orchopeas leucopus (Baker)
- *Pitmys pinetorum pinetorum* (Lec.), Pine mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Megabothris asio (Baker)
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse

Stenoponia americana (Baker)
- *Microtus pennsylvanicus pennsylvanicus* (Ord), Meadow mouse
- *Pitymys pinetorum pinetorum* (Lec.), Pine mouse
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Doratopsylla blarinae Fox
- *Blarina brevicauda* (Say), Short-tailed shrew

Epitedia wenmanni Rothschild
- *Peromyscus leucopus leucopus* (Raf.), White-footed mouse

Factors Influencing Control of the Walnut Aphid

A. E. MICHELBACHER and CLARK SWANSON,
University of California, Berkeley

From an insecticidal point of view a nicotine dust if applied under proper conditions results in exceptionally good control of the walnut aphid, *Chromaphis juglandicola* (Kltb.). It certainly ranks high among control practices, and is a treatment that can usually be counted on to give satisfactory results. During the past season the walnut aphid proved to be a serious pest over much of the walnut-producing section of northern California. At Linden in San Joaquin County the seasonal population trends of the pest were rather closely followed. This was particularly true of the orchard in which our codling moth plots were located. From these observations it was concluded that although a nicotine dust results in a satisfactory kill of aphids, good control is probably dependent upon proper timing of applica-

tions, and some knowledge of the relation that exists between the aphid population and its natural enemies. If this relation is not understood, there is danger of an application of nicotine dust doing more harm than good. Evidence to support this was found in the orchard in which the codling moth plots were located.

From early in the season the ashy-gray ladybird beetle, *Olla abdominalis* (Say), was abundant, but despite this there was a rather rapid build-up in the aphid population. By May 9, aphids were secreting large amounts of honeydew. On May 18 aphids were abundant, but were apparently causing little injury. Ladybird beetles were found in all stages of development. Although the ashy-gray was by far the most numerous, other species were present. Syrphid fly adults were also observed in numbers. By May 29 aphids were abundant but no more so than on May 18. Ladybird beetles had become very abundant. *Hippodamia* adults were everywhere on the trees, and ashy-gray ladybird beetles were numerous in all stages of development. Syrphid flies were noted in moderate abundance, and lace wings were present. Although some damage had been done by the aphids, it was rather evident that the predator population had developed to a point where it was rapidly reducing the aphid population. Despite the fact that the natural enemies were gaining the upper hand, the orchard was dusted with a nicotine dust on June 5. The kill obtained was excellent, and on June 7 the only aphids observed were a very few winged forms. This elimination of aphids left the predators without food and as a result, later surveys revealed ladybird beetle adults feeding upon their own eggs. Apparently the lack of food caused many of the predators to leave the orchard, and the predator population nearly disappeared. By July 24 the aphid population started to build up rather rapidly, and gave every evidence of reaching serious proportions. The ladybird beetle population was very small. On August 7 there was a very large aphid population and much damage was being done. Few ladybird beetles in any stage of development were observed although syrphid fly and green lacewing larvae were rather common.

The orchard was dusted with a nicotine dust for a second time on August 8. This resulted in a satisfactory control of the aphids for the remainder of the season. The second dust would have been applied sooner had it not been for the fact that the orchard had been irrigated which made it impossible to move equipment through it any earlier.

It is probable that the second and very destructive aphid population would not have developed if the first application of nicotine dust had not been applied. There is no doubt that it was applied too late to do much good for all evidence, as already stated, indicated that the predators were rapidly reducing the aphid population. Although some damage was apparent, little more was likely to occur. Applying the dust at that time, completely upset the natural balance. It appears that the predator population was nearly driven from the orchard. After this happened there were probably large migrations of winged aphids from non-dusted orchards to the dusted orchard. In the absence of natural enemies these aphids were able to build up an extremely large population in a relatively short period of time.

In the absence of the first dusting it is probable that the aphid and its natural enemies would have reached equilibrium at some point that would have prevented the occurrence of the second very large and destructive population. This conclusion is substantiated by numerous observations in the Linden Area. Undusted orchards were examined that in the main showed less aphid damage than the one in which the codling moth plots were located.

The above has not been presented to discourage the use of nicotine dust for the control of the walnut aphid, but to point out that timing of applications is a very important consideration. It is very likely that satisfactory control would have resulted if the first dust application had been applied as soon as the aphids became abundant and before any injury whatsoever could be detected. This timely dusting probably would not so adversely upset the natural balance. Further, observations on the timing of dust applications will be made during the coming season, with the object in view of determining the most satisfactory time to apply nicotine dusts.—11-20-44.

Cybocephalus Established in California

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The predator, *Cybocephalus*, sp., first introduced into Orange County in 1934, has been recently determined to be established there. This Nitidulid was collected in the Orient by H. Compere of the University of California in 1933 and sent to the Citrus Experiment Station which supplied the Orange County Insectary with a stock for reproduction and distribution on California Red scale, *Aonidiella aurantii* (Mask.)

Over 20,000 *Cybocephalus* were reared in the Insectary from Red Scale propagated on banana squash. Liberations were made on Red scale on both commercial citrus and ornamental hosts in localized areas throughout the County. On subsequent inspection no *Cybocephalus* could be found on these hosts.

Ten years later it has been found quite numerous on two different scales. It was feeding on *Diaspis boisduvalii* (Signoret) infesting native Opuntia cactus near the town of Costa Mesa, and also was very well established on *Diaspis cocois* (Lichenstein) infesting the palm, *Cocos plumosa*, around Santa Ana. It does not appear at the present time that the population of either of these scales has been greatly reduced by the work of this predator.—11-9-44.

LITERATURE CITED

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The Importance of Ecology in Insect Control

THE PROBLEMS that confront the economic entomologist are varied and many of them will take years to solve. Successful control is based upon an understanding of the biology of the insect involved, and of the various environmental factors that either favorably or unfavorably affect the species. The problem is so vast and the challenge offered in many cases is so great as to nearly defy a solution. As a result, satisfactory control of many of our insect pests still remains to be mastered.

New insecticides are continually being developed and, although these aid in control, they do not serve as a substitute for a knowledge of the biology of the insects involved. Proper timing of applications of insecticides is only possible where the biology and seasonal population trends of an insect are known. Although nearly every entomologist recognizes this fact, many workers have to handle so many problems that they are unable to devote sufficient time to the study of insect biology.

Because of these innumerable unsolved problems, the field of economic entomology offers fertile opportunities for men who have been thoroughly trained in basic and fundamental phases of entomology. There is an ever increasing need for such persons both in experiment stations and in the commercial field. The study of the insects themselves will fall most largely upon those entomologists who are associated with experiment stations and similar research institutions. Although much of their time should of necessity be spent on the study of insecticides, such workers must not lose sight of the fact that they are responsible for most of the biological and ecological research. In the main it is their responsibility to determine the proper time of application, and to seek out information that will allow for accurate prediction as to the seriousness of an insect attack. Their studies should enable them to judge the effect of physical and biological influence exerted upon any particular pest. They should gather the information concerning the pest and interpret it in terms that will lead to most efficient control. The factors that might result in biological control should be accurately known and if they are not determined, much time and material may be expended that is unnecessary. In fact, the improper use of an insecticide might result in a more serious loss than would have occurred had it not been applied. A constant check on the relation that exists between the host and its natural enemies must be followed.

The factors that favor effective biological control as well as those which are unfavorable must be determined. The effect of climate or weather conditions upon the pest must be carefully studied, with the ultimate hope that all control will be based upon sound biological facts.

It should be the aim of every entomologist to be able to give the exact reasons why a certain insecticide control program should be followed or instituted. To give for the reason "insurance" is not sufficient, although with our present state of knowledge, this is often necessary. The time will probably never come when the knowledge concerning insects will be so complete that it will never be necessary to apply insecticides for the purpose of insurance against a serious infestation. The balance that exists in many cases between the pest and the natural factors which tend to keep it in check may be so delicate as to make accurate predictions impossible. Where there is doubt as to natural control, based upon a knowledge of sound biological facts, the application of an effective insecticide as an insurance is justified. However, in general, recommending the application of an insecticide as an insurance is an admission of failure as to our complete understanding of the factors that influence the insect population.

Improving our methods of insect con-

trol is a goal toward which we must strive, and it can only be reached by insisting that students in economic entomology be thoroughly trained in the basic fundamentals of the subject. The training should be such that they consider the economic pest from all of its ecological aspects. It should be studied in relation to the complex in which it occurs, and not wholly as a separate entity. Only by doing this can the true biological and ecological picture be obtained.

A person who has the opportunity to study the biology of an insect is truly fortunate. It is his privilege to be able to explore a new field. The satisfaction that comes as the problems start to unfold is extremely gratifying and gives one the enthusiasm and desire to carry on. If a person cannot experience these reactions, it is very doubtful if he should ever attempt to conduct investigations that deal with the ecological aspects of entomology.

There are countless numbers of cases where biological studies have made invaluable contributions to the control of insects. Such studies have resulted in the proper timing of insecticide applications, to effective cultural control, and to successful biological control. Many of these studies have shown that the critical period over which an insecticide can be most effectively applied is only a few days to a week in extent. Once the critical period is determined, the problem that arises is how to utilize the information to best practical advantage. In many cases, the factors that determine the critical period are too obscure or too complicated for the farmer to adequately determine for himself. Even though he could, he is often so busy with other problems that he has no time to devote to this matter. He needs help, and much is given him by the extension service, experiment stations, and other organizations that are interested in insect control; but this aid is often not sufficient because of a shortage in personnel capable of handling this work. At critical times the entire services of one to several qualified persons is needed to advise on the timing and supervision of insect control measures. For most effective control of the corn earworm, *Heliothis armigera* (Hbn.), on tomato and the alfalfa caterpillar, *Colias eurytheme* Bdv., on alfalfa, services of specially trained entomologists are needed. These two pests are mentioned because they represent a group where the necessity for control varies, within a given district, between districts, and from season to season. One field may be seriously attacked by the corn earworm while another not far away may be only very lightly infested. An infestation may start in late July or may be delayed until September. With the alfalfa caterpillar the situation is even more complex. One field may be completely defoliated by the pest, while another, only separated from it by a road, will escape damage altogether. Because of the spotty nature of the infestations caused by the insects just mentioned, it would appear that the timing of control measures, and the determination of their necessity, would be extremely difficult. Yet if the population trends of the insects are carefully known, an efficient control program can be put into operation. Insecticides would then only be applied where necessary and economic control would be brought about with a minimum danger of upsetting the balance of nature.

If they are to be successful, men to fill such positions must be good entomologists and keenly interested in their work. They will certainly need to have a broad ecological point of view. The question is who should employ these men? Should they be connected with the extension service, or should industry assume that responsibility? Moves to have insect control carried out under trained supervision have already been attempted by some private companies in California and probably elsewhere. That this is the best means of handling many of our most serious pest problems is being demonstrated, and this system will probably come into far wider use. It is an excellent means of putting into practice the practical findings that result from research investigations. It is a field that should offer opportunities to many entomologists and one that should be encouraged.

A. E. MICHELBACHER

PROCEEDINGS OF THE FIFTY-SIXTH ANNUAL MEETING

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Hotel New Yorker, New York, N. Y., December 13, 14 and 15, 1944

THE PRELIMINARY BUSINESS MEETING

The Preliminary Business Meeting was called to order by President Essig at 7:30 P.M. on December 13, 1944 in the North Ballroom of the Hotel New Yorker with approximately 75 members present. The first item on the agendum was the Secretary's Report.

REPORT OF THE SECRETARY

Heretofore we have listed on our program an open executive committee meeting. This served as the place where the reports were presented of standing and special committees except nominations, membership, resolutions and any others that had to be carried over to the final session. Objection having been raised to the name as failing to convey the idea of the exact functions of the meeting, the change was made with the hope that a larger number of members would participate in the business of the Association. I have separated my secretarial report from the financial statement as there are a number of matters that should engage your attention for possible action at the final session.

At the present time, the membership of the Association stands at 1644. However, this does not represent precisely the actual membership status as it is made up of two who are two years in arrears, thirty-four foreign members and thirty-five who are three or more years in arrears. During the year, sixteen were dropped for varying reasons, twelve have died and there is one resignation.

The total subscription list is 2,419 of which 2,022 are subscribers in the United States. It also includes seventy subscriptions being held for the American Library Association. There are pending 161 applications.

I would like to have the members give consideration to the desirability of extending our meetings to four days in the future. This program would have been much more attractive if more time had been available.

In the field of economic entomology, this Association is recognized as the most important organization. Its JOURNAL likewise is accorded first place. You are proud of its accomplishments but few of you realize that its present position is due to the vision of its pioneers, the unremitting work of a few, notably A. F. Burgess, and the support of most of the working entomologists in this country and Canada. The editorial burden has been carried at considerable personal sacrifices by E. P. Felt, T. H. Frison and L. M. Peairs.

The Association and its JOURNAL can be materially improved by concerted effort of all members through study of its problems of organization and financing and more careful preparation of manuscripts, entomological reporting and closer cooperation with the editor.

The finances will be discussed on Friday. Suffice to say that the Association is solvent, is meeting increased war-time costs and is operating economically. The members should give consideration, however, to an increase in dues. Nowhere is such a fund of timely information on the subject matter of your profession obtainable for such a small sum. The cost of the JOURNAL to members is only $3.00. Members get, virtually free, the *Indices*, although starting in 1937 fifty cents from each $2.00 dues has been set aside to help defray the costs of printing the *Indices*. In addition they receive biannually *Entoma* and special rates on monographs, etc. Possibly dues, and the cost of the JOURNAL to non-members, should be increased. Members should ask themselves whether any comparable benefits can be obtained in any other organization for the payment of such meager dues.

There are several aspects of our organization that should be given careful thought and study at this time in preparation for a greater usefulness of entomology in the solution of post war American problems.

Several members have broached the subject of greater cohesiveness in our professional inter-relations. Whether the time is ripe for closer organization needs the consideration of every member of each of the two major organizations. It should be approached with certain well defined objectives based on the greatest good to entomology, to the two organizations and to the individuals.

Both organizations are going concerns, serving their memberships in many desirable ways and both are working together in harmony. They occupy separate areas of utility with little or no overlapping. Hence any consolidation must be based on whether such consolidation will be better for entomology, better for the organizations and help the individual.

If we can judge by the history of organization in medicine, engineering and chemistry, it would seem that a consolidation would improve conditions within the profession of entomology. Certainly those professions best organized have had a preferred position with respect to manpower and opportunities for service in the present conflict. Entomology has been subservient to engineering and to the medical sciences in this war and although there has been a greater realization of the importance of entomology, there has been no admission by either of those professions that their technique in meeting disease conditions is predicated on entomological knowledge. A closer knit organization might help in the future to bring about a more general knowledge among the people generally and the leaders in particular of the essentiality of the science of entomology.

Whether consolidation would be helpful to each Association would depend upon the type of organization evolved and the amount of money and energy the membership would be willing to expend in purely internal organization efforts, in expanding publication channels and in propaganda, if you will, to inform the public of the aims and objects, the subject matter and the methods of entomology.

The individual would undoubtedly profit by economies that should accrue in a single compact organization and would profit directly by expanded publication channels and indirectly by the propagandizing of the importance of entomology.

There is, however, another type of over-all organization that should be given careful consideration. That is the institute, wherein all agencies having any entomological function might be coordinated for well defined objectives, each retaining its autonomous control; but contributing ideas, problems and funds toward the common advancement of the profession of entomology.

Conceivably such an institute might speak authoritatively for all entomologists, might improve the profession and be the medium for the accurate and persistent presentation of entomology to the public. Had such an institute been in operation in 1939, the usefulness of entomological endeavor in the present conflict might have had greater professional recognition and standing, through authoritative representation to the Committee on Scientific Research and Development, the Armed Forces and the War Manpower Commission.

Such an institute could and should function towards improvement of instruction, procedures and organization in entomology. It indubitably should have as one of its prime functions the education of the public as to the essentiality of entomology in food and fiber production, in the protection of man and animals from disease and annoyance, in the beneficial aspects of biological control and in the cultural value of entomology, dispelling for all time the idea that an entomologist is a long-haired collector of butterflies. The definition, the spelling and the connotations of entomology should be familiar to everyone.

Such an institute should encompass the two major entomological organizations, state and local groups, the insecticide societies, the pest control operators, the mosquito control workers and any other groups working directly or indirectly towards entomological ends. It should have well organized propaganda objectives and methods using that term in its original and proper intent and it should have a representative board of directors and an able executive secretary properly financed to carry on the program.

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS
STATEMENT OF RECEIPTS AND DISBURSEMENTS FOR THE FISCAL YEAR ENDED NOVEMBER 30, 1944

	TOTAL	JOURNAL	ASSOCIATION	INDICES I–V	INDEX VI	INDEX VII
Receipts:						
Subscriptions	$ 7,516.62	$ 7,516.62				
Advertising	411.20	411.20				
Reprints	896.73	896.73				
Back Numbers and Miscellaneous	858.71	858.71				
Life Memberships	200.00	200.00				
Dues	3,191.50		$2,395.60			$ 797.90
Common Names and Miscellaneous	6.00		6.00			
Sales of Indices	213.70			$105.00	$ 108.70	
Bond Interest	50.00		50.00			
Total Receipts	13,344.46	9,883.26	2,449.60	105.00	108.70	797.90
Life Membership Receipts to be transferred to Permanent Fund Savings Account in Prince Georges Bank & Trust Co.	200.00	200.00	0	0	0	0
Adjusted Receipts	13,144.46	9,683.26	2,449.60	105.00	108.70	797.90
Disbursements:						
Auditing and Accounting Fees	65.00	32.50	32.50			
Surety Bond for Secretary	12.50	6.25	6.25			
Safe Deposit Box Rental	3.60		3.60			
Printing	8,754.62	8,754.62				
Engravings, drafting, etc.	475.20	475.20				
Honorarium, Secretary, Business Manager and Editor, Editorial Assistant	875.00	437.50	437.50			
Stenographic and Clerical	280.58	140.29	140.29			
Traveling	24.20		24.20			
Committee Expenses	91.08		91.08			
Branch Expenses:						
Cotton States (Includes $147.19 for Mimeographing)	395.69*		395.69			
Pacific Slope	59.10		59.10			
North Central States	82.71*		82.71			
Postage, Stationary and Supplies	362.43	181.21	181.22			
Telephone and Telegraph	49.04		49.04			
Express	6.68	6.68				
Refunds	38.39	38.39				
Insurance on Books, Furniture and Equipment (3 yr. Prem.) ($19.86 Unexpired Insurance as of Nov. 30, 1944)	29.38		29.38			
Stenotyping of Proceedings of Annual Meeting	164.45		164.45			
Notary Fees	2.75		2.75			
Bank Service Charges	47.54	23.77	23.77			
Total Disbursements	11,819.94	10,096.41	1,723.53	—	—	—
Excess of Adjusted Receipts Over Disbursements	1,324.52	413.15*	726.07	105.00	108.70	797.90
Add: Balance November 30, 1943	3,507.93	1,529.52	3,778.11	333.61	2,913.60*	780.19
Balance November 30, 1944	$ 4,832.45	$ 1,116.37	$4,504.18	$438.61	$2,804.80*	$1,578.09
This Balance is Represented by the Following:						
Prince Georges Bank & Trust Co. (Checking Account)	$ 3,032.45					
Less Amount Due Savings Account for Life Memberships	200.00					
	2,832.45					
U.S. Defense Bonds, Series G (2½% Interest)	2,000.00					
Total (As Above)	$ 4,832.45					

* The two starred amounts include part of the travelling expenses of the President to the Branch meetings. This was explained at New York. Actual normal expenses for the Cotton States Branch was $37.91. No expenses have ever been chargeable to the North Central States Branch.—E.N.C.

STATEMENT OF PERMANENT FUND

Balance, November 30, 1943, as per previous report		$25,498.40
Income for the period:		
Interest received from securities	$292.87	
Interest received from savings deposit	63.00	
Interest credited to book value of U.S. Bonds	300.00	
Life Memberships	200.00	
Total Income		855.87
Balance, November 30, 1944		$26,354.27

This balance is invested as follows:

	Par Value	Book Value	
Securities:			
Province of Ontario, 5's	$ 2,000	$2,000.00	
U.S. Treasury Bonds, 2½'s	3,000	2,948.00	
U.S. Savings Bonds, Series A	5,000	4,600.00	
U.S. Savings Bonds, Series D	10,000	8,500.00	
U.S. Defense Bonds, Series G, 2½'s	2,000	2,000.00	
Total Securities			$20,084.00
Bank Deposit (Savings Account):			
Prince Georges Bank & Trust Co. (2%)		6,070.27	
Due from Checking Account (Life Memberships)		200.00	6,270.27
Total Investments in the Permanent Fund			$26,354.27

STATEMENT OF AUDITOR

College Park, Md., December 11, 1944

Dr. E. N. Cory
American Association of Economic Entomologists
College Park, Maryland
Dear Dr. Cory:

I have made an examination of the accounts and financial records of the American Association of Economic Entomologists for the fiscal year ended November 30, 1944 and, without making a detailed audit of the transactions, have tested the accounting records of the association and other supporting evidence, by methods and to the extent deemed appropriate.

In my opinion the accompanying statements of receipts and disbursements of the association and the permanent fund present fairly the results of its operations for the fiscal period and the cash positions of its funds at November 30, 1944.

Respectfully submitted,
CHARLES L. BENTON, JR.
Certified Public Accountant

EXECUTIVE BOARD MEETING
DECEMBER 13, 1944

Hotel New Yorker, New York City

In attendance: President Essig, F. L. Thomas, H. B. Weiss, E. N. Cory.

1. After an explanation in regard to the charges of the Cotton States Branch, it was recommended that: hereafter any allocation of funds to branches or sections beyond the ordinary charges incident to the announcement of meetings and routine business must be arranged for in advance.

2. The auditor's report was presented and analyzed. Due to the reduction in income from dues of service men remitted, loss of subscriptions in foreign countries and increased costs of printing, the checking account is at its lowest ebb. The committee decided to recommend that the uninvested savings fund of the Permanent Fund be transferred to the checking account to provide adequately for current expenses and to meet the initial costs of Index VII. Passage of this recommendation would involve the waiving of notice as required in Article V, Section 3 of the Constitution.

3. It was recommended that the incoming President re-appoint the same committee that was charged with codifying the statements of policy and regulations of the Association.

4. A recommendation of an increase in the amount allowed for clerical help in the Office of the Secretary from $240.00 per annum to $480 per annum was passed.

5. The request of the Secretary for authorization to have the auditor so set up the book account of the several indices that surpluses in any one or more index accounts may be credited to deficits in the accounts of other numbers was made. This followed the recommendation of the auditor.

6. The committee authorized the publication of Index VII, 1940–1945, involving the payment of an honorarium of $500.00 to Dr. Stanley W. Bromley for the editing. The material is nearly ready for checking by the U. S. National Museum and should be in the hands of the Editor by June, 1945.

7. The petition of a group of entomologists for the formation of a section to be known as the Insecticide Section was thoroughly discussed and approved in principle. The recommendation made to the final business meeting was that the formation of the section be approved in principle with a change to a more repersentative name such as the Section of Industrial Entomology, the aims and objects of the Section to be worked out and more clearly set forth by a committee of entomologists engaged in the field of industry working with the Executive Committee.

8. The committee recommended that if at all possible, a meeting be held in 1945 and requested Dr. Thomas to visit Dallas to look into the hotel situation. Kansas City was also suggested. Invitations had been received from Cincinnati, St. Louis, Philadelphia, Pittsburgh, Buffalo and Grand Rapids.

9. The committee recommended a four day session.

FINAL BUSINESS MEETING

December 15, 1944

The financial report of the Auditor was read with explanations by the Secretary especially as relating to the Branch charges. In the absence of the Secretary, travel vouchers of the President to regional meetings were charged to the Branches. An explanation of these charges is made in a footnote to the Auditor's report. The report was approved.

The following recommendations of the Executive Committee were approved:

1. That allocation of funds for Branch or Section expenses, other than ordinary charges for notices of meetings, postage, etc. must be arranged for in advance.
2. That the uninvested savings fund of the Permanent Fund be transferred to the checking account to meet current expenses and to meet initial costs of Index VII. Reduced income and higher publication costs made this recommendation necessary. It was pointed out that passage of this recommendation would involve the waiving of notice as required in Article V, Section 3 of the Constitution.
3. That the publication of Index VII be undertaken.
4. That the petition of a group of entomologists for the formation of a section to be known as the Insecticide Section be approved in principle, with a change of name that would more clearly indicate the purposes and function, such as the Section of Industrial Entomology. It further recommended that the aims and objects be more thoroughly worked out and more clearly set forth by a committee of entomologists from industry working with the Executive Committee. This was discussed at some length by several members.
5. That a meeting in 1945 be held if at all possible.
6. That a four day meeting be substituted for the three day meeting. This was passed on a show of hands.

NEW BUSINESS

Dr. Hugh Glasgow reported that at a meeting of the Eastern Branch, Dr. G. S. Langford was elected Editor of *Entoma*. Other members of the Editorial Committee are C. C. Hamilton, J. L. Horsfall, Harry B. Weiss, R. C. Roark, Mrs. R. L. Busbey, C. V. Bowen, and William Boyd.

Dr. Dietz made a suggestion that for the sake of uniformity, in the writing of the name DDT, that the name be dichlor diphenyl trichlorethane, dropping out the final o in dichloro and in trichloro. This suggestion was withdrawn for action with the suggestion that it be considered by the Committee on Insecticide Terminology and the Editor of the Journal.

Friar L. Thompson initiated a lengthy discussion predicated upon the desires of the entomologists representing industry to have an entire day set aside for discussion of problems of industry but later his motion was withdrawn after the entire subject had been gone into exhaustively by a number of members. The Constitutional provision for the formation of a Section was read and the function of the Program Committee explained. Discussion was participated in by Peairs, Campbell, Weed, Stearns, Dietz, Rohwer, Gemmell, Burgess and others. Subsequently as a result of this discussion about the desires of members representing industry, a petition was presented for the formation of a Section. This was considered by the Executive Committee and the action of that Committee is included in the recommendation presented at the Final Business Session.

President Essig commended the splendid report on the entomological achievements of Thomas Jefferson as prepared by H. B. Weiss. The report was not read but will be printed in the JOURNAL.

A. F. Burgess discussed the importance of committee work and the necessity of individuals taking their responsibilities seriously and making provision for the presentation of the results of their work if circumstances prevented the attendance of the member.

REPORT OF THE COMMITTEE ON NOMINATIONS

Mr. G. F. MacLeod read the report of the Committee on Nominations and the following officers were duly elected:

D. L. VAN DINE T. H. FRISON E. N. CORY
President *Vice-President* *Secretary-Treasurer*

(See Official Roster for complete list of Committees and Officers).

The Nominating Committee feels that, in the interests of the Association, the full membership should have the opportunity to express its preference in the selection of the higher officers, particularly the president and vice-president. It recommends, therefore, that a special committee be appointed by the incoming president to study the means by which this may be accomplished and to submit a report, with recommendations for such changes in manner of election as may be agreed to, at the next annual meeting.

C. P. CLAUSEN
ROGER B. FRIEND
G. F. MACLEOD, *Chairman*

Dr. D. L. Van Dine, the newly elected President, was escorted to the chair by ex-presidents F. C. Bishopp and J. S. Houser. President Van Dine accepted the honor conferred upon him with appropriate remarks.

President Van Dine inquired whether the time and place of the next meeting should be discussed and decided at that time and J. S. Houser moved that the matter be left to a decision by the Executive Committee.

Adjournment.

REPORT OF THE RESOLUTIONS COMMITTEE

The Committee on Resolutions wishes to submit the following report:

1. WHEREAS: We have enjoyed a very successful and worthwhile meeting under somewhat adverse conditions, we wish to express our thanks to the following agencies:
   1. The Local Committee in charge of arrangements.
   2. The Program Committee for arranging such a splendid program.
   3. We wish especially to express our appreciation to the Hotel New Yorker, and its Sales Manager, Mr. Royal Ryan, for so ably taking care of our requirements.

2. WHEREAS: As a war measure, a number of so-called house organs such as the Extension Entomologist were suspended and

WHEREAS: These publications contained much timely and valuable information which is greatly needed to carry out the most effective insect control program

THEREFORE: Be it resolved that the publication and distribution of the Extension Entomologist be resumed at the earliest possible date and further be it resolved that a copy of this resolution be sent to the Secretary of Agriculture and the War Food Administrator.

3. WHEREAS: In recent years the activities of the Federal Government in maintaining the Insect Pest Survey have been very materially curtailed and the Insect Pest Survey Bulletin has been discontinued to the material disadvantage of field workers.

THEREFORE: Be it resolved that this Association recommends that (1) the issuance of the Insect Pest Survey Bulletin be resumed at the earliest possible moment and also that the survey be furnished with adequate funds and personnel to carry on this work not only in the limited way it was done before the war, but in a manner to make it vastly more effective, both in carrying on its own activities and in assisting in the various State's activities in establishing or expanding state surveys.

All survey activities of the Bureau of Entomology and Plant Quarantine should be centered in the Insect Pest Survey Division.

4. WHEREAS: It is a proven fact that correct pollination of a majority of our fruit, vegetable and seed crops is an essential of approved agricultural practices, and

WHEREAS: The continued application of poisons, especially in dust form, has killed thousands of colonies of honey bees and has seriously reduced the number of other important pollinating insects on farms and in our principal farming areas, and,

WHEREAS: It is important to protect our pollinating insects from further destruction to safeguard the production of fruit, seed and vegetable crops;

THEREFORE: Be it resolved that this Association recommend to its members that in giving their recommendations for the application of insecticides they emphasize the need of (1) preventing the application of all substances toxic to pollinating insects to plants in bloom, and (2) of confining the toxic material to the crops treated in order to prevent the destructive drift of poisons to adjacent fields.

5. WHEREAS: Since the Planning for Entomology in the Post War World Program will be of little value unless the suggestions contained in the reports of the various committees are acted on and since these recommendations concern teaching, experimental work and extension work:

THEREFORE: Be it resolved that copies or resumes of these reports be distributed to all administrative officers concerned.

6. Be it resolved that the Secretary be instructed to send the cordial greetings and best wishes of the members to Dr. L. O. Howard.

CLARENCE E. MICKEL
Z. P. METCALF
ROY E. CAMPBELL, *Chairman*

REPORT OF THE COMMITTEE ON MEMBERSHIP

Owing to the absence of all members of the Membership Committee, President Essig appointed a Temporary Membership Committee consisting of G. M. Bentley, A. F. Burgess, L. G. Smith, H. B. Weiss and Harvey Sweetman, Chairman. They recommended and the following applicants were approved:

Abell, Earl F., 93 Ellsworth Ave., Toronto, Canada
Adamson, etc.

The following four applicants who were not included in those considered by the committee have since been approved by the Executive Committee subject to a vote of the membership at the next annual meeting.

Joseph T. Bashour, 120 West 70th St., New York, N.Y.
Charles E. Gerhardt, 605 Volunteer Bldg., Atlanta, Ga.
Wallace J. Morse, Nesmith Hall, Durham, N.H.
Earl F. Rothemich, Sherwin Williams Co., Bound Brook, N.J.

The Temporary Committee on Membership, due to insufficient time, has been unable to make a thorough study of the question of membership, admittance, etc. Since the Permanent Committee on Membership has not completed its study and presented a report, it is recommended by the Temporary Committee that the entire question be returned to the Executive Committee of the American Association of Economic Entomologists for further consideration.

NEW MEMBERS 1945

Abell, Earl F., 93 Ellsworth Ave., Toronto, Canada
Adamson, Alastair M., Imperial College of Tropical Agr., Trinidad, B.W.I.
Allmon, Charles W., R. 1, Industry, Pa.
Avens, Alfred W., N.Y. Agr. Expt. Station, Geneva, N.Y.
Bahgat, Monir, Agr. Attache, The Royal Egyptian Legation, Washington, D.C.
Bashour, Joseph T., 120 W. 70th St., New York 23, N.Y.
Bellemare, E. R., Univ. of Montreal, Montreal, Canada
Benbow, John G., R. 1, Box 65 B, Arvin, Calif.
Berg, Morris, Cushing Genl. Hosp., Framingham, Mass.
Bodenstein, Otelia Frances, Ocean Springs Boat Base, Ocean Springs, Miss.
Boyd, William M., 170 Millerick Ave., Trenton, N.J.
Boyers, Miriam, 1745 Eastburn Ave., Box 57, New York, N.Y.
Bream, Robert O., 1400 Base Line Rd., Azuza, Calif.
Bryant, Clyde C., B 147, Salt Lake City 8, Utah
Bumgardner, Rush J., R. 1, Box 1021, Orange, Calif.
Bunch, Edward L., 3106 Legation Rd., Hyattsville, Md.
Burnett, Douglass, Jr., 1882 Karolina Ave., Winter Park, Fla.
Burns, Theodore C., Pahokee, Fla.
Caldis, Panos D., Calif. Packing Corp., 101 California St., San Francisco, Calif.
Caldwell, Archibald H., Jr., California Spray Chem. Corp., Richmond, Calif.
Calkins, LaVere A., 304 W. Mary St., Yates Center, Kan.

Callaghan, George F., 31 Ebony Dr., Brownsville, Tex.
Chamberlin, William F., 2140 Oxford St., Berkeley, Calif.
Clancy, Donald W., 139 Valley Rd., Charlottesville, Va.
Cole, Elsie, 155 Biology Bldg., Univ. of Wis., Madison
Conroy, John H., Det. 1802nd S.C.U., Borden General Hospital, Chickasha, Okla.
Corson, Esek O., Second and Addison Sts., Berkeley 2, Calif.
Cowan, E. Karl, Knight St., Interlaken, N.Y.
Cowan, Frank A., 1003 N. Big Spring St., Midland, Tex.
Cowan, Frank T., 411 W. Garfield Rd., Bozeman, Mont.
Cowden, Lloyd D., 626 N.W. 9th, Pendleton, Ore.
Cronin, Timothy C., 32 Fremont St., Bloomfield, N.J.
Crosby, Bernard D., Post Engineer's Office, Ft. Geo. G. Meade, Md.
Curran, C. H., Museum of Nat. History, 15 W. 77th St., New York 24, N.Y.
Daehnert, Raymond H., 6327 N. Kenmore Ave., Chicago, Ill.
Detjen, Gustav H. H., 303 West 42nd St., New York 18, N.Y.
Dobrovsky, T. M., 4425 Bienville Ave., New Orleans 19, La.
Dodge, Harold H., 1407 U.S. Appraisers Bldg., San Francisco 11, Calif.
Doehlert, Charles A., Pemberton, N.J.
Doty, Alfred, Dow Chemical Co., Midland, Mich.
DuChanois, Francis R., 721 Park Ave., Corpus Christi, Tex.
Edgecombe, Samuel W., Box 471, Doylestown, Pa.
Erskine, Donald E., 235 Oakdale Ave., Mill Valley, Calif.
Euting, Neil A., R. 4, Box 11, Oconomowoc, Wis.
Evans, Kieth E., 1305 Canal Ave., Idaho Falls, Idaho
Every, Robert W., Box 1697, Billings, Mont.
Fluno, Helen J., 781 Antoinette Ave., Winter Park, Fla.
Fox, Charles J., 15 Broad St., Aylmer, Quebec, Canada
Francis, William J. F., 2901 Taylor Way, Tacoma, Wash.
Frazier, Andrew F., 44 East Vernon Ave., Phoenix, Ariz.
Frear, Donald E. H., Penn. State College, State College, Pa.
Freville, Wm. F., Box 299, Lexington, Ky.
Fulmer, W. L., 505 Boylston North, Seattle, Wash.
Gardner, Arling A., Box 1315, Huron, S.D.
Geluwe, John Van, Box 231, Middletown, N.Y.
Gerhardt, Charles E., 605 Volunteer Bldg., Atlanta, Ga.
Gieser, Arthur, 7415 Fillmore Dr., Dallas 9, Tex.
Gillaspy, James E., Hq. and Hq. Sq. AAFTAC, Orlando, Fla.
Goelbert, Raymond, 71-15 65th St., Glendale, Long Island, N.Y.
Goodwin, Melvin H., Jr., 605 Volunteer Bldg., Atlanta 3, Ga.
Greenwood, Douglas E., Conn. Agr. Expt. Sta., New Haven, Conn.
Gyrisko, George, Cornell University, Ithaca, N.Y.
Hagmann, Lyle E., 124 Bruce St., Scotia 2, N.Y.
Hammond, Harry J., Sr., 1016 N. Jackson St., Milwaukee, Wis.
Harden, Philip H., 2473 Verbena St., New Orleans, La.
Hardy, T. H., 2119 Rutland, Houston, Tex.
Haring, Robert C., 24 Kathwood Rd., White Plains, N.Y.
Harper, Robert W., R. 1, Box 38A, Chico, Calif.
Harston, George B., Box 785, Powell, Wyo.
Haynes, Harry L., 11 Llewllyn Pl., New Brunswick, N.J.
Hazelrig, J. B., 606 N. 9th St., Birmingham, Ala.
Hendrick, Mrs. Anola, 710 Lake Formosa Dr., N. Orlando, Fla.
Hess, George M., Jr., 3710 Beach Dr., Seattle 6, Wash.
Hibbs, Edwin T., Truck Crop Investigation Lab., Alta Loma, Tex.
Hinchey, Edna, Orlando Laboratories, Orlando, Fla.
Hinman, Edwin J., 407 W. Alderson, Bozeman, Mont.
Hovanitz, William, Box 997, Tallahassee, Fla.
Hutchins, Francis E., 33 Winfield St., East Norwalk, Conn.
Ikawa, Miyoshi, Univ. of Wis., Madison
Johnston, Charles A., Rm. 201 Custom House, Baltimore, Md.
Jones, Jack D., 0-413784, APO 471, c/o PM, San Francisco, Calif.
Jones, V. Rhys, R. 1, Box 417, Paradise, Butte Co, Calif.
Jonson, William L., 495 S. Arroyo Pkwy, Pasadena, Calif.
Joyce, Charles R., Box 992, Brownsville, Tex.
Karlovic, John K., 335 Brunson Ave., Benton Harbor, Mich.
Kerbey, George F., 4039 S. Broad St., Yardville, N.J.
Kilgore, Lowell B., 1050 30th St., Washington 7, D.C.
Kinney, Lyle, Bear Creek Orchards, Medford, Ore.
Knowles, F. L., 874 Union Ave., Memphis, Tenn.
Krauss, Noel L. H., 2437 Parker Pl., Honolulu 5, Hawaii
Laidlaw, Harry H., Jr., FSC Lab., Jamaica Plain 30, Mass.
LaPlante, Albert A., N.Y. Agr. Expt. Sta., Geneva, N.Y.
Leopold, Henry F., ShurDeth Exterminating Co. One N. LaSalle St., Chicago 2, Ill.
Levi-Castillo, Roberto, Box 759, Guayaquil, Ecuador, S.A.
Lindsay, Dale R., 1306 E. 28th St. Austin 22, Tex.
Link, Karl Paul, Univ. of Wis., Madison
Longworth, Duncan E., 75 Lee Ave., Rockville Center, N.Y.
Loring, Lindsay B., Okanogan, Wash.
Maines, Warren Wm., 279 W. Main St., Moorestown, N.J.
Mallia, Michael J., 39 Whiting St., New Britain, Conn.
Maple, John D., 246 N. Painter Ave., Whittier, Calif.
Mayer, Elmer L., 1606 Palmetto Ave., Sanford, Fla.
McCain, W. H., 11 St. Mary's St., Dayton 1, Ohio
McGuire, Lt. Judson U., O-1108156, APO 322, PM, San Francisco, Calif.
Meyer, Herbert, 165-33 Hillside Ave., Jamaica, N.Y.
Militzer, Herman C., 2905 118th St., Toledo 11, Ohio
Miller, H. D. Oliver, 331st AAF Base Unit, Sqd. H., Barksdale Field, Shreveport, La.
Mills, Lindley E., 303 State Theater Bldg., Kalamazoo, Mich.

Montgomery, Vayron H., 210 Post St., San Francisco 8, Calif.
Morgan, Stephen R., Box 340, Honolulu, Hawaii
Morse, Wallace J., Nesmith Hall, Durham, N.H.
Nelson, Howard C., 3517 N. Atlantic, Spokane 12, Wash.
Newsome, Leo Dale, Shongaloo, La.
Nicholson, H. Page, 300 Essex Bldg., Norfolk, Va.
Noonan, Joseph E., 9 Wyoming Ave., Lynbrook, N.Y.
Ogloblin, Alejandro, Sanabria 3120, Buenos Aires, Argentina
Olsen, Ruth F., 22 East 38th St., New York 16, N.Y.
Olson, Theodore A., 8th Serv. Comm. Lab., Ft. Sam Houston, Tex.
Osmun, John V., Hq. 2nd Serv. Comm., Governors' Island, N.Y.
Ostlind, Herbert J., Ostlind Pest Control Co., Corvallis, Ore.
Pearce, W. M., 8143 Castro Valley Blvd., Hayward, Calif.
Patton, Robert L., Cornell Univ., Ithaca, N.Y.
Pearson, Elmer B., 2839 Shattuck Ave., Berkeley 5, Calif.
Pearson, Oscar, 1333 4th Ave. South, Fargo, N.D.
Pfadt, Robert E., Univ. of Wyoming, Laramie
Phillips, Grace R., 373 William St., East Orange, N.J.
Pinckard, Joseph A., 16 Rooney St., Santa Cruz, Calif.
Quarterman, Kenneth D., Box 789, Panama City, Fla.
Rebstock, J. D., Hercules Powder Co., Brunswick, Ga.
Reeves, William C., Hooper Foundation Med. Res., San Francisco, Calif.
Rhodes, W. W., Westtown, Chester Co.
Ridgway, Wilbert O., Box 1788, Amarillo, Tex.
Rillett, Robert O., Univ. of Wis., Madison
Rings, Roy W., 1158 Oakland Ave., Columbus, Ohio
Robertson, Oris T., Presidio, Tex.
Rodda, John A., 2003 Elsinor Ave., Baltimore, Md.
Rogers, Earl E., Research Center, Beltsville, Md.
Rogers, Edward, 61 Hamilton Pl., New York 27.
Rohwer, G. G., Box 316, Burgaw, N.C.
Rothemich, Earl F., Sherwin Williams Co., Bound Brook, N.J.
Scott, H. Eldon, Ontario Agr. College, Guelph, Ontario
Schroeder, Herman O., 623 W. Concord Ave., Orlando, Fla.
Scudder, Harvey I., Carter Memorial Lab., Savannah, Ga.
Semans, Frank M., North Jackson, Ohio
Shockley, C. Wilfred, 131 Speer Blvd., Denver, 3, Colo.
Skoog, Fred E., Montana State College, Boozeman
Smith, Sam S., 5250 21st Ave., Sacramento, Calif.
Stark, A., Wasatch Chem. Co., 2225 S. Fifth East, Salt Lake City, Utah
Summers, Harvey S., Box 24, Pendleton, Ore.
Sun, Yun-Pei, Cornell University, Ithaca, N.Y.
Taylor, Frank H., School of Public Health and Tropical Medicine, Univ. of Sydney, Australia
Thomas, Athalie P., 3461 Avocado Ave., Riverside, Calif.
Tingle, Jay P., Box 134, Meridan, Miss.
Truman, Lee C., C. E. 0-519499, R & U Branch, 5th Service Command, Ft. Hayes, Columbus, Ohio
Twyman, Edwin B., John Powell y Cia, 1535 Condarco, Buenos Aires, Argentina
Wallace, Hugh E., 210 Santa Rita Ave., Modesto, Calif.
Wallace, Melbourne D., Brigham Young Univ., Provo, Utah
Wallace, Philip P., 123 Huntington St., New Haven, Conn.
Walsh, Ralph, 29 Broadway, New York 6, N.Y.
Walters, E. G., 405 El Paso Ave., Port Arthur, Tex.
Wasson, James Stanley, APO 980, c/o PM, Seattle, Wash.
Weisgerber, Adolph F., 340 N. 7th St., Newark 7, N.J.
Wellhouse, William T., Box 971, Brownsville, Tex.
Whitlock, Stuart D., 103 Hillside Ave., Chatham, N.J.
Willard, Frances, 211 Elmwood Place, Austin 21, Tex.
Wilson, Bruce V., Rm. 844 Federal Bldg., Christopher St., New York 14, N.Y.
Wilson, Harold G., 415 Boone St., Orlando, Fla.
Wolff, William G., Box 1697, Billings, Mont.
Zapf, Robert A., 57 N. Laurel St., Ventura, Calif.

REPORT OF JOINT COMMITTEE ON MILITARY ENTOMOLOGY

Your Committee on Military Entomology has continued to extend assistance to the Army, Navy and Public Health Service in the procurement of well-qualified men for entomological service and has assisted entomologists in their efforts to be assigned to activities in which their training and experience can best be utilized.

The increase in personnel of the Sanitary Corps authorized this year made possible the commissioning of a number of additional entomologists largely for service with malaria survey and control units. These additional men were recruited from available enlisted personnel rather than from among civilians. Some of these men had acquired competent experience while serving on malaria survey or control units and with their background of entomological education and often experience in some branch of entomology before entering the Service, they should make effective entomological officers. There are still available in the ranks a number of well-trained entomologists, some of whom may be commissioned as calls come for additional men in this field. It should be pointed out, however, that the needs for entomological officers have been largely met.

The idea seems still to prevail that medical officers or sanitary engineers, rather than entomologists, must direct the work of malaria control. The training and experience of many entomologists would not fit them fully for the handling of mosquito control projects. However there are certainly many who have both the training and experience with large-scale undertakings, including the procurement and handling of labor and equipment, to direct effectively any type of insect control. Efforts are being made in the direction of having these competent entomologists given opportunity to show their ability in this field. Such action would tend to relieve in small degree the present shortage of medical officers and sanitary engineers.

The seriousness of the malaria situation in our major theaters of operation was such as to cause the activation and field assignment of many malaria

survey and control units. Other problems in the entomological field such as control of dengue mosquitoes, flies, and scrub typhus mites have come to the fore. This has resulted in the utilization of these units on other problems than malaria and even their assignment to areas where no malaria problem exists.

The attention of the Committee has been directed on a number of occasions to confusion which has arisen in connection with the procurement in the field of entomological officers. In view of the fact that officer requirements for officers of all classes have been largely met, the activities of the Officer Procurement Service are being curtailed. However, it may be appropriate to set forth briefly the functions of this service and explain some of the reasons for confusion. The Officer Procurement Service is responsible for bringing to light suitable officer material in many categories. That Service interviews candidates, prepares proper papers, and acts as an early screening organization. When authorization is received for the procurement of additional officers word is sent to the Officers Procurement Service and not infrequently the needs are met by candidates already having applications filed. Occasionally procurement officers, in their zeal to submit lists of candidates are inclined to overestimate the needs and are not sufficiently familiar with the qualifications demanded for technical positions.

Some consideration has been given by the Committee to matters relative to the postwar training and placement of entomologists. Also to aiding young men in the Service who are interested in taking up entomology when they are mustered out. It is our opinion that this is a field that should receive the full consideration of both entomological societies and that steps should be taken by them to provide adequately for this service.

Your Committee would like to draw attention to the contribution being made to the field of medical entomology and to the furtherance of our war effort by the research groups of the Bureau of Entomology and Plant Quarantine at Orlando, Florida, and Beltsville, Maryland and the taxonomic unit in Washington, D. C., also by certain other agencies. The results of this research and service are well received by the military and are being promptly put into effect.

At the present time there are approximately 220 entomologists in the Sanitary Corps of the Army. Of these about 120 are overseas. In the Hospital Volunteer Corps Service of the Navy there are about 100 entomologists engaged in entomological work in the Service, of which about 90 are overseas. The rank of the entomological officers in the Sanitary Corps is approximately as follows: 5 Lieutenant Colonels, 19 Majors, 100 Captains, 58 First Lieutenants, and 39 Second Lieutenants. The rank of the entomological officers in the Hospital Volunteer Corps Service of the Navy is as follows: 56 Ensigns, 34 Lt. j.g., 6, Lt. s.g., 2, Lt. Com.

A number of entomologists are serving in an entomological capacity in a number of other branches of the military. A few commissioned officers and a number of civilians are carrying on entomological work in the Corps of Engineers and a number are assigned to military government. Several of the latter are doing general sanitary work including entomology.

ERNEST N. CORY
ROBERT MATHESON
F. C. BISHOPP, *Chairman*

REPORT OF THE COMMITTEE ON CODLING MOTH FOR 1944

For a number of years the Committee on Codling Moth has made arrangements with the Bureau of Entomology and Plant Quarantine for collecting, mimeographing, and distributing an annual pool of information on current research. Your Committee feels that this service is of great value to those workers interested in codling moth research and that it should be continued, especially since it should contain reports of the experimental results with the new insecticide DDT. Arrangements were again made with the Bureau for this service. It is urged that all workers contribute to the pool.

Until recently the Committee has also sponsored an annual conference of those workers engaged in research on codling moth. It has voted against holding such a conference this year, because of wartime restrictions on travel.

In 1941, 1942, and 1943 a list of suggested lines of research was included in the report. The Committee feels that since the list as published in the JOURNAL, Vol. 37, No. 1, Feb., 1944, pp. 174, 175, covers the field of codling moth research quite completely and is available for reference, it would be a needless repetition to publish it again this year.

Suggestions from any of the members of the Association are always welcome.

LEONARD HASEMAN EDWIN GOULD
L. F. STEINER W. S. HOUGH
B. F. DRIGGERS L. G. GENTNER, *Chairman*

REPORT OF THE COMMITTEE ON CO-OPERATION WITH THE PEST CONTROL OPERATORS

Last year this committee reported that it had prepared a draft of a proposed law to regulate the practice of pest control. Although this draft was not published, comments were invited from both entomologists and pest control operators. No written comments have been received. This committee wishes to call to the attention of the operators and the entomologists that many phases of such regulations come properly under the supervision of health officers and building commissions, as well as other municipal and state authorities. For example, safety to human beings is an important element in the use of fumigants and poisons, and structural strength is important in the modification of any building. When accidents occur, due to any mistake in practice, such authorities are likely to impose regulations promptly. This leads to the loss of initiative on the part of entomologists and operators and may lead to confusion in the attainment of the aim of the operators, namely, pest control.

In discussing possible fields of cooperative effort with officials of the National Pest Control Association, the latter emphasized the need of further research. This necessitates well defined goals and the elimination of gaps in our knowledge. In order to get clearly in our minds what information is necessary and what gaps exist, as well as to give the pest control operators in concise form what information we already possess, this committee suggests that the American Association of Economic Entomologists cooperate with the National Pest Control Association in compiling a handbook of pest control. Inasmuch as the National Pest Control Association already has under way the compilation of a handbook

on materials used, the section in which we would be particularly interested would refer to the entomological phases only. The material should be concise, in tabular form where possible, and to the point. It should not attempt to give specific directions where the art of pest control alone is concerned, but should leave this to the operators. It should contain such items as (a) common and scientific names of the pest, with a brief practical description including, if necessary, line drawings well labeled; (b) its life cycle, habits and habitat, with particular emphasis on conditions leading to abundance; (c) the methods of controlling it. The details of publication, authorship, etc. should be worked out through the cooperation of the pest control operators and the entomologists, but it is suggested that the material be so arranged that supplementary information could be added as acquired. It is furthermore suggested that the Committee on Cooperation with the Pest Control Operators meet with their cooperative committee each year and undertake a revision of the information in the handbook where essential.

E. G. LINSLEY
O. W. ROSEWALL
R. B. FRIEND, *Chairman*

REPORT OF THE COMMITTEE ON POPULAR ENTOMOLOGICAL EDUCATION

In the preparation of this report your Committee surveyed the last twelve monthly numbers of the Bibliography of Agriculture prepared by the Library of the U. S. Department of Agriculture for listings of periodicals, books, bulletins, and processed material carrying entomological articles, and checked with the Bureau of Entomology and Plant Quarantine for the number of press and radio releases which were cleared through the Bureau. The Committee also wrote to one entomologist in each state, and to the Dominion Entomologist in Canada, for a list of publications, exhibits, and motion pictures, and for the number of radio releases known to have been released in the state. The survey covered as nearly as possible the period November 1, 1943, to October 31, 1944, inclusive. Replies were received from about one-half of the states. These were representative of the country. Admitting that the survey is far from complete, some rather interesting information was revealed.

Nearly 300 different periodicals, exclusive of those issued by entomological or apicultural associations for their membership, were found which carried over 600 popular entomological articles during the period checked. Included in this list were a number of national magazines, such as *The Saturday Evening Post* and *Country Gentleman*, regional magazines, such as *The New England Homestead*, and *The Saskatchewan Farmer*, and commodity magazines, such as *The American Fruit Grower* and *The Cattleman*. Undoubtedly there are many periodicals not found in this survey which may have carried popular entomological articles. It is to be regretted that space will not permit the listing of all of the 300 periodicals referred to above, because if they were called to the attention of the entomologists, more use might be made of such publications in the dissemination of entomological information. Also, in addition to these periodicals, there must be many not now carrying entomological articles that would be willing to do so if the matter were called to the attention of the editors by the entomologists.

In addition to the above, the *Extension Service Review*, issued monthly by the Federal Extension Service, and similar monthly publications issued by many of the State Extension Services carried popular entomological articles. Also, the County Extension Services and the educational branches of the County Farm Bureaus issued monthly publications. It is impossible to approximate the number of such publications issued. However, the Extension Entomologist in one state reported 96 County Farm Bureau organizations which published monthly material of an educational nature in newspaper or magazine form. These publications vary in size from 4 to 15 pages, depending on the size and the finances of the county. As a rule each monthly publication has up to 3 or 4 entomological articles in it. On this basis, 2000 to 3000 entomological articles appeared in the county magazines of that one state.

The State Extension Services issued more than 100 bulletins, circulars and other printed matter relating to entomology, and many times that number of processed or mimeographed material. Most of these were well-illustrated and written in a manner that would make them easy to read and understand. Many of the Experiment Station bulletins and those from other agencies were entirely of an entomological nature or carried popular entomological information. Numerous leaflets and folders issued by insecticide companies gave timely information on insects and their control, as well as the catalogs issued by hardware and seed stores. The names of 10 books of a popular entomological nature, published during the past year, have come to the attention of your Committee.

Despite the reduction in allocation of paper for newsprint, competition with war information, and all the publicity associated with a national election, great numbers of entomological articles were carried in daily and weekly newspapers and also in a number of the Sunday Magazine sections of the newspapers. It is impossible to approximate the number of entomological articles appearing in the daily or weekly press, or the number released by state workers. The Bureau of Entomology and Plant Quarantine, however, issued 66 press releases of various kinds during the 12 month period covered by this report. The Canadian Division of Entomology reports the release of 30 *Farm News* and press copy articles and two special articles. One entomologist reported 465 news clippings of an entomological nature from the papers in his state for a four months' period. Applying this figure for a twelve months' period, and for all states, it is obvious that many thousand articles of an entomological nature were carried in the newspapers of this country during the past year.

Indications suggest that the radio is continuing to gain popularity as a means of disseminating entomological information. Our survey revealed that 18 States reported an average of 30 broadcasts given by the extension or other entomologists. The number of radio talks ranged from one in one state to 75 in another state. In addition to the longer talks, many 2 to 3 minute briefs were used. In most of the states, copies of the radio talks were mailed to the county agents and rebroadcast over local stations. The estimated number of these rebroadcasts given in the reports from three states was 1,573, or an average of 524 per state. Seventy-three broadcasts were released through the Bureau of Entomology and Plant Quarantine. In addition to the above, one television script was approved, four transcriptions were made, and three recordings for the Union of

South Africa were prepared. The Division of Entomology of Canada reports 13 radio releases and special broadcasts.

Exhibits may not have been used as extensively during 1944 as in some previous years because so many fairs were cancelled as a war measure. There were, however, a number of smaller entomological exhibits used, especially in connection with the Victory Garden program. To a lesser extent exhibits were used to illustrate subjects such as cattle grub control, European corn borer control, and cotton insects and their control. Many of the smaller exhibits were so prepared and packaged for shipment that they could be used repeatedly. As an example, one State reported that 20 exhibit cases of insect material were prepared in triplicate and exhibited in different localities in the State. Some were displayed by the larger Department Stores.

The shortage of film reduced the number of motion pictures and still pictures taken during the past year. A few pictures, however, were made by the state people. Extensive use was made of the motion pictures which were available. The motion picture industry displayed a greater appreciation of entomology by referring to the subject in a number of popular films and built at least one feature picture, "Once Upon a Time," on the characterization of an insect. Color slides served a very useful purpose and were used by practically all entomologists in discussing popular aspects of insects and their control. Despite the fact that no new entomology slidefilms were prepared during this past year, 393 copies of those available were purchased from the manufacturer of such films.

The extension of entomological information to the members of the armed forces will have a lasting benefit, because the returning veterans will not soon forget their exposure to the subject. It was acquired through the many talks, posters and motion pictures presented to them; also through their experience with the insects, the aerosol bombs, and the insect repellents in the field of operations. Furthermore, many enlisted men have been familiarized with various entomological problems through their assignment to units responsible for insect control. An important project was set up at the Orlando, Florida, laboratory of the Bureau of Entomology and Plant Quarantine, to aid military officials responsible for the control of insects and the diseases which they carry. About 400 Army and Navy Medical Officers, Sanitary Engineers, and Entomologists haue attended monthly 4-day conferences. Representatives of the Bureau gave the latest available information and demonstrated the most recent formulas and technique which they have developed. A number of foreign countries have been represented in addition to officials from all parts of this country.

The above information suggests that a great amount of effort has been directed toward popularizing entomology. When the amount of work which has been done is compared with the relative importance of entomology to our national economy, it is obvious that only a good start has been made. If entomology is to attain the professional standing its deserves, each one of us will need to take advantage of every facility at his disposal to call to the attention of the public how some phase of entomology affects the everyday life of each man, woman, and child.

J. A. HYSLOP
J. T. CREIGHTON
J. O. PEPPER
M. P. JONES, *Chairman*

REPORT OF THE COMMITTEE ON THE RELATION OF ENTOMOLOGY TO CONSERVATION

In presenting this, its eighth annual report, your committee recognize that during the year very little effective work has been done, and that there are practically no definite accomplishments to be announced in this highly important field. Recommendations have been made, the possible lines of study have been explored, and a few short papers have appeared, but beyond that we can acknowledge only failure to progress definitely in a field which offers unlimited opportunities not only for acquiring data of great interest in pure science but also for establishing practical biological controls of certain injurious insects. Postwar plans can well include research along these lines.

On the practical side, we may reasonably expect to experience another period of agricultural adjustment. Perhaps we should look forward to a period of reduced crop acreages, and possibly to the return of the ever-normal-granary program. Although a discussion of the conservation of food supplies is somewhat beyond the original scope of this committee, it may be appropriate to stimulate interest in this field also. After World War I we were unprepared for these adjustments, and as a result we made serious blunders. Certainly we should profit by this experience and be prepared to make suitable recommendations to cope with such problems as the proper handling of idle land so that these untilled acres will not become breeding grounds of injurious insects to threaten the crops in adjoining fields.

We wish to cast no reflection, but as an illustration of the need for cooperation and education in reducing certain insect losses we would state as our opinion that fully 90 per cent of the insect problems encountered in connection with the storage of corn in some of the midwestern states were due to errors in building construction, to wrong management, to poor judgment, and to ignorance of the importance of insects attacking stored grain and their control. When the agencies concerned were in trouble they were very cooperative. In soliciting aid from entomologists they placed many of their facilities at the disposal of the research workers. Their primary interest, however, was in "getting out of hot water," and they were not much concerned with the need for promoting and utilizing fundamentally sound research. Eventually, rather comprehensive experiments were set up; but with our entrance into World War II and a stimulated demand for corn, reserve supplies were dumped—in some cases without even notifying the cooperating research agencies—so that installed equipment might be salvaged.

There is need for continued research and educational programs as well as for careful organization and planning in the postwar era. In order that the information needed in solving these problems may be promptly gathered and systematized we think it appropriate that each cooperating agency be responsible for one or more well defined phases of the subject. In our opinion one year's unified cooperative study is worth several years of so-called coordinated independent study.

Your committee think more attention should be given to our indigenous beneficial insects. Perhaps we should consider ways and means of conserving this valuable asset and even of increasing the effectiveness of natural biological control of destructive species. The Fish and Wildlife Service has per-

formed miracles in increasing the numbers of many game birds and mammals. There is no reason why entomologists cannot discover means of increasing the populations of certain valuable insect and other parasites and predators and of the various bees which, as pollenizers, increase fruit and seed production. The close relationship between pollinators and seed production has been mentioned innumerable times, but it is still receiving scant attention by most entomologists. Any project that involves beneficial insects should include studies of the new insecticide DDT, for it kills certain beneficial forms as well as many injurious ones. Large scale tests involving this chemical have been proposed for field and forest conditions during 1945. This type of research is the most effective way in gaining full information on the use of a material having the properties of DDT.

Entomologists who specialize on aquatic insects have played an important part in increasing the numbers of game fish. It was due largely to their research that we learned how important insect life is to the welfare, growth, and even life of the finny tribe. We have learned also that even the expedient of cutting away the brush along streams may be detrimental to the welfare of the fish inhabiting them, because without the overhanging brush, insects would not be so likely to fall into the water.

Philip F. Allan, of the Soil Conservation Service (JOUR. ECON. ENT., Vol. 37, No. 2), has pointed out the availability and potential usefulness of the local soil-conservation districts in the study and control of insect pests. Entomologists should take advantage of these 1,100 conservation units comprising over 640 million acres of land organized by and for farmers. By this means research projects on ecology can be set up over practically the whole United States, and no doubt would furnish information on the control of a wide variety of insect pests.

Your committee feels that the need for entomologists as well as biologists should be emphasized in postwar plans having to do with the conservation of our national resources. Perhaps a start in this direction might be accomplished by soil conservation agencies.

F. P. KEEN — G. C. DECKER
S. A. GRAHAM — F. E. WHITEHEAD
H. H. STAGE, *Chairman*

REPORT OF SPECIAL COMMITTEE ON DDT

We feel that never in the history of entomology has a chemical been discovered that offers such promise to mankind for relief from his insect problems as DDT. There are limitations and qualifications, however.

Subject to these, this promise covers three chief fields: public health, household comfort, and agriculture. As public health we include control of the insects which carry diseases that have scourged humanity, such as malaria, typhus and yellow fever. Household comfort is taken to cover such things as flies, fleas, bedbugs and mosquitoes. Agriculture includes not only farms, gardens and orchards but forests, livestock and poultry.

In the public health field DDT insecticides are so much more effective than previous weapons against malaria mosquitoes that for the first time there is a practical hope for eradicating that disease from this country. DDT proved in Italy that it is the first and only practical control for typhus. In the household field its amazing lasting effect promises relief for months from flies, mosquitoes and fleas. In the case of bedbugs, eradication from the American home has become a possibility.

In agriculture, it is promising against a wide variety of destructive pests. These include most potato insects, many orchard and vineyard pests, numerous vegetable insects, as well as the chief insect enemies of vitally important seed crops. It appears to be effective against the pink bollworm and outstanding against the Japanese beetle, two of our worst imported pests. It promises also a more practical control of the pests which ravage thousands of square miles of forest, and against many of those which harass livestock.

DDT will not kill all the important insect pests. It will kill many beneficial insects which are allies of mankind against the destructive species. Because of its toxicity to a wide variety of insects, its large-scale use might create problems which do not now exist. To illustrate, it is a superior insecticide for control of codling moth on apples, but in some sections at least will kill certain natural enemies and thus release other insects which may then become major problems.

The research reports emphasize that we have had no time to develop entirely satisfactory mixtures and dosages of DDT insecticides, or the methods and timing of application for many possible uses. Modern agricultural pest control often requires mixing several materials in combination treatments, and we know little of DDT's compatibility with many of these. Researches thus far were made with a material which was produced under pressure for military needs, and which is not necessarily the best form for agriculture.

We do not know enough about effects on plants, animals and soils. While most plants were not harmed by DDT insecticides in the experiments, injury to squash, corn, tomatoes and possibly fruit trees was reported. DDT is toxic to animal life when large amounts are taken internally or absorbed through the skin from oil solutions, but reports indicate a reasonable margin of safety. In the light of our present knowledge, heavy deposits on edible parts of plants should be avoided. Reports show definite toxicity to cold-blooded animal life including fish and frogs. There has not been time to learn the possible cumulative effects on soils.

More and larger-scale experimentation is needed. Enough DDT for such research in 1945 should be provided.

Signed:

G. F. MACLEOD — GEORGE C. DECKER
F. C. BISHOPP — CHAS. E. PALM
GEO. M. LIST — A. FLEBUT
S. A. ROHWER, *Chairman*

THE CROP PROTECTION INSTITUTE
Report for the Year 1944

Among federal and state laboratories, and among industrial companies, the search for new insecticides and fungicides has been very active throughout 1944. Apparently, we are well embarked in a period in which we shall see various new chemical compounds for the control of insects and plant diseases. Undoubtedly some insects that hitherto have not been controlled in adequate degree will yield to new measures. This is true, for example, with certain carriers of human diseases, such as body lice and mosquitoes. It is becoming true, also, as regards some destructive plant diseases.

Among the larger industrial companies new laboratories are being established which have been or will be staffed in part by entomologists and plant pathologists, and which will be conducted on a scale paralleling that prevailing in experiment stations. Necessarily, only a large company can install adequate facilities and provide for a sufficiently large staff. Even a large company may logically enter this field only gradually and may profitably wait until it has developed some promising products before it embarks on the large investment represented by a plant of its own.

The function of the Crop Protection Institute remains, therefore, similar in nature and scope to that which has prevailed for a considerable period of years. Its service may be summarized as follows:

(1) To assist smaller companies in their exploration of new compounds or by-products which might be of value in control of insects or plant diseases.
(2) To administer development projects for larger industrial organizations who do not possess facilities and a staff of their own.

Even a large industry, with extensive research laboratories, may find the Institute able to serve an important purpose because it can provide unbiased administration of a research program. The Institute is a fact-finding organization. Its technical committees, and the workers that it employs, can examine data without prejudice for or against. They are not likely to hurry a material onto the market before it is ready. In this respect the Institute has always offered, and still offers, advantages over laboratories established by an industry, even though impressive in size.

A summary of Institute projects for 1944 follows:

1) *Armour and Company.*—A combination of blood albumin and a fixative agent has been the subject of investigation throughout the year. Results to date have been definitely encouraging.

Laboratory studies in spray applications have been conducted at the Pennsylvania experiment station, under the direction of Dr. H. W. Thurston, Jr. Mr. John B. Harry has been employed part time. The material selected for evaluation through the earlier part of the year was basic copper sulfate, which would lend itself readily to analysis of residues, both before and after application of artificial rain. The combination of blood albumin and fixative agent gave higher degree of retention than any other adhesive agent. Field tests of this combination on potatoes did not yield data, because of adverse conditions as regards both rainfall and incidence of disease.

More recently laboratory studies have included acid lead arsenate, basic lead arsenate, and calcium arsenate, as materials for evaluation. With each of these the combination of blood albumin and fixative agent gave higher retention than the best tenacity agent available, though somewhat less retention than with basic copper sulfate.

Studies of blood albumin and fixative agent as a tenacity agent for dust applications were conducted at the University of New Hampshire. Mr. W. J. Morse was employed through the year at two-thirds time. Where dusts were applied to leaf surfaces which were moist, a high degree of retention was recorded. The optimum amount of fixative agent in a dust, such as calcium arsenate, was 2 lbs. in 100 lbs.

2) *Carbide and Carbon Chemicals Corporation—Fungicide Investigations.*—Extensive studies which have been in progress at the Boyce Thompson Institue, under the supervision of Dr. S. E. A. McCallan, have continued through 1944. Dr. Richard H. Wellman has been employed as Research Associate, and has been provided with additional help, which has included several persons on part-time basis.

These studies are steadily accumulating an understanding of the relation of molecular configuration to fungicidal activity in at least certain groups of compounds. This broad aspect of the work is clearly one of its important contributions, which, in the long run, will be of value both to the supporting company and to the progress of science. Certain organic compounds have continued to show encouraging activity. In addition to organic compounds, a long series of inorganic substances has been under study. Among these several appear to be remarkably promising.

Through the cooperation of Dr. H. W. Thurston, Jr., several promising new materials have been given field tests at the Pennsylvania experiment station. These tests have been so designed as to afford extensive and trustworthy data.

3) *Carbide and Carbon Chemicals Corporation—Insecticide Investigations.*—Location of these studies was transferred this year to the Boyce Thompson Institute, where they were placed under the immediate supervision of Dr. Albert Hartzell and Dr. S. E. A. McCallan. A successor to Dr. E. N. Woodbury, who resigned in the latter part of 1943 to take a position elsewhere, has not yet been secured. However, Mr. Donald P. Connola was employed as Technical Assistant, and has been actively at work with an exploratory schedule. The organic compounds which had been studied by Dr. Woodbury were given parallel tests. The intent was to secure a background on which chemical groups might be selected, in which further explorations would logically be indicated. A large volume of data have been accumulated. In addition to utilizing insect cultures available at the Boyce Thompson Institute, advantage was taken of the temporary abundance of some insects occurring naturally outdoors.

4) *The Geigy Company, Inc.*—The intensive studies which were in progress in 1943, exploring possibilities of the new chemical DDT (dichloro diphenyl trichloroethane) have been continued through 1944. Dr. George R. Ferguson has continued as Research Associate. In addition, Mr. C. C. Alexander was employed full time, beginning September 15, 1944.

One of the principal functions of this project is to study the relationship of DDT to solvents and liquid carriers, and its relationship to various inerts as dry diluents. A large number of representative liquid carriers has been included in the investigation. More than thirty inert diluents for dust have been studied. From these investigations several formulations have been developed which are safe on plants and which permit DDT to perform to advantage.

On the basis of these essential experiments, contact was established with state experiment station men throughout the country, and recommendations were forwarded to the Geigy Company, and to Washington, concerning allocations to state men for their experimental programs.

During the past summer field tests were maintained by Dr. Ferguson with the assistance of Dr. J. G. Conklin. In the latter part of the year both Dr. Ferguson and Mr. Alexander have made extensive trips, in order to discuss field results with state entomologists in various areas. Laboratory and

greenhouse work has centered at the University of New Hampshire. A similar program is expected to prevail for 1945.

5) *General Chemical Company, Inc.*—Investigations for this company have included studies of sulphur compounds for the control of the tomato psyllid (under the supervision of Dr. George M. List, of Colorado experiment station); studies of new fungicides (under the supervision of Dr. S. G. Lehman, at the North Carolina experiment station); preliminary exploration of new organic fungicides and insecticides; and preliminary studies of anthelmintics.

6) *The Mathieson Alkali Works, Inc.*—A complex amine which had been developed at the company's laboratories was given further study from time to time, as a toxicant in fly sprays and as a constituent of formulae for use in aerosols. This work has not been continuous but has been given attention as developments warranted.

7) *Rohm & Haas Company.*—A large number of new organic compounds, developed in the company's research laboratories, have been given preliminary spore tests. In addition, certain compounds which showed adequate promise, have been used in replicated field plots. This work is carried on in close cooperation with the research department of the supporting company. Field plots parallel similar plots maintained by the company, both in Pennsylvania and elsewhere. As in past years, investigations have been under the supervision of Dr. J. G. Horsfall, of the New Haven, Connecticut, experiment station. A new organic fungicide is now on the market, and has been given the name Dithane. Some difficulties encountered at the start in large-scale manufacture have now been overcome. Other new compounds of promise are in process of development.

Beginning in July 1944 Mr. Raymond W. Barratt was employed as Research Associate in this project, succeeding Dr. Wendell D. Henry.

8) *U. S. Industrial Chemicals, Inc.*—This project is concerned with utilization of a by-product derived from the manufacture of industrial alcohol from molasses. For convenience the product has been given the name Curbay MS. Following fifteen months of intensive study at the New Jersey experiment station, a continuation of the work was provided for, in order to conduct additional laboratory studies, and to arrange for field tests in several localities. The laboratory studies were placed at the Boyce Thompson Institute, under the supervision of Dr. P. W. Zimmerman. Field plots were arranged for in central, western, and southern states, as well as in the East.

W. C. O'KANE

REPORT OF THE REPRESENTATIVE OF THE NATIONAL RESEARCH COUNCIL

The annual meeting of the Division of Biology and Agriculture of the National Research Council was held at the National Academy of Sciences and National Research Council Building, Washington, D. C., April 8, 1944, Dr. Robert F. Griggs, Chairman, presiding.

Representatives from 18 member organizations were in attendance, in addition to 6 special and members at large.

The outstanding business transacted was as follows:

Invitations were issued to the Soil Science Society and to the Wildlife Society to become members of the Division.

It was voted to recommend to the Executive Board of the Council that a Fellowship Board in the Agricultural Sciences be established.

The Chairman of the Division reported on a resolution adopted February 12, 1944 by the Executive Committee which read as follows:

> "The Executive Committee strongly urges greater support for agriculture and a more active interest in its problems. It believes that the best way of bringing this about is through the more active cooperation of biologists and agriculturalists which can be furthered best by maintaining the present organization of the Division."

This resolution was discussed at some length on March 8 by a group of agricultural leaders called into conference by the Chairman of the Division. As a result of this meeting it was decided to recommend to the Executive Board of the Council that a Board of Agricultural Science be established.

Action was taken to establish a Personnel Information Committee for inquiry and advice to the biological societies to assist with personnel problems such as are apt to be faced during the period of demobilization.

The Division recommended to the Executive Board that the Bimonthly Report of the Division be printed as a bimonthly journal.

All committees of the Division, with the exception of the Committee on the Applications of the Electron Microscope were asked to continue. A list of these committees include:

Committee on Animal Nutrition
Committee on the Biological Processes of Ageing
Committee on Crop Protection
Committee on the Ecology of Animal Populations
Committee on Fellowships
Committee on Fisheries Resources
Committee on Research on Food Resources of Coastal Waters
Joint Committee on Forestry
Committee on Instruction in the Biological Sciences
Committee on Human Heredity

A resolution was adopted emphasizing the importance of the continuance of scientific meetings during the war.

Your representative called the Division's attention to the inroads being made on the populations of pollinating insects, the seriousness of which is so obvious when one considers the steady reduction in the per-acre production of many seed crops, particularly the legumes. The matter was referred to the Joint Committee on Wildlife.

Acting upon the recommendation of the Division to establish an Agricultural Science Board, the Executive Board of the National Research Council authorized the establishment within the Division of such an organization to be known as the Agricultural Board. The scope of operation of the new board is to be left to the members of the board. The Chairman of the Division has asked various leaders in agriculture to submit nominations for membership of the board. The function of the Agricultural Board will parallel somewhat that of the existing Food and Nutrition Board of the Division. The new board will also work in close conjunction with the newly authorized committee on Fellowships in

Agriculture. The purpose of the committee is to encourage the establishment of more fellowships in agriculture so that candidates interested in agricultural research will have equal chance with persons competing for fellowships in the pure sciences.

Your representative has experienced difficulty in trying to envisage the work of the Division. Its very name, Biology and Agriculture, is indicative of the tremendous scope of its possible activities. For this reason perhaps its efforts have had to be thinly spread; and, since its members are all actively connected with research organizations of one kind or another, specific accomplishments by the Division often seem somewhat intangible.

In looking back over the reports of the Division your representative is impressed with the fact that Entomology has not played a prominent part in the deliberations of the Division. In the past, recommendations relating to various phases of entomology have been made to the Division. Usually these have come in waves—too many problems proposed at one time. As a result little or nothing has been accomplished. The fault may lie with the Division or it may lie with the entomological societies. At all events it appears that entomologists are not taking full advantage of the resources of the National Research Council.

During the past year your representative has not been asked to present any matters of business to the Division. It might be well, however, for the Association to consider one or two outstanding entomological problems of national scope for which moral and possibly, eventually, financial support might be forthcoming through the offices of the Division.

Respectfully submitted,
JAS. I. HAMBLETON

REPORT OF DELEGATE OF THE A.A.E.E. TO THE MEETING OF THE A.A.A.S.

Cleveland, Ohio, Sept. 11–16, 1944

I attended this convention as the representative of the National Roster of Scientific and Specialized Personnel and the American Association of Economic Entomologists. During the period of Sept. 11 to the 14th, I attended both sessions of the Council of the A.A.A.S., the special meeting called by Dr. Flynn on Biological Abstracts, the Academy Conference, the Union of American Biological Societies, Section F and one or more sessions each of the American Society of Parasitologists, Ecological Society of America, American Society of Zoologists, Botanical Society of America, American Society of Plant Physiologists, and the General Sessions of the Association which were held in the evenings.

The following notations from the meetings of the Council may be of interest to Entomologists:

The minutes of the previous meeting were not read. The new officers will be elected this fall by mail ballot sent to the delegates. The time and place for the next meeting will be determined in the same manner. The new constitution was recommended for adoption after critical debate and an unsuccessful attempt to pass four amendments. When the constitution was placed before the whole convention on Monday evening, there was one vote against it which was sufficient to prevent its adoption since the constitution provided that adoption must be by unanimous vote. A three-fourths vote will suffice to adopt it next year.

Mr. Ware Cattell, who alleges he was unlawfully discharged from the Editorship of Scientific Monthly and who is suing the Association for damages and back salary, appeared before the Council to state his case. Dr. Moulton and Dr. Caldwell made no rebuttal or defense since the question will be thoroughly dealt with in a court this fall.

The membership of the Association was reported to be 25,700 which included approximately 2500 new members in 1943–44. A higher percentage of the membership has their dues paid to date than usual.

The circulation of *Science* is now about 17,000 copies per week.

The monthly *A.A.A.S. Bulletin* costs the Association only about 14 cents a year for each volume.

Under Dr. F. L. Campbell's able editorship of 16 months the circulation of the Scientific Monthly has increased approximately 30 per cent.

The report on the publication and sale of the Symposia was favorable in all respects. Those on Medical Sciences have had the largest sale. A symposium on Hormones is in press and one on Mammary Cancer in Mice is in preparation. Copies of the Symposia are sold for the cost of printing and selling. The need of more non-technical writing for the public was stressed.

The Council requested a published, detailed agenda distributed well in advance of the meeting and indicated its wish to exercise more fully its authority and responsibilities with reference to the Association.

I introduced a motion to the effect that the President of the American Association for the Advancement of Science appoint a committee of three (amended to five) to study the National Roster for the purpose of better acquainting this Association with the Roster and to make recommendations both to the Association and the Roster as to how the Roster may serve scientists more effectively. It was carried unanimously.

I attended an informal meeting of an interested group of scientists to discuss the unification problem in the Agricultural and Biological sciences. This is a live issue and the question is being seriously studied. Dr. D. W. Bronk of the University of Pittsburgh is serving as chairman of this committee, and Dr. F. A. Browne of Northwestern University is the secretary.

This question also was briefly discussed at the meeting of the Union of American Biological Societies. Doctor Flynn reported that Biological Abstracts has now balanced its budget.

At the meeting of Section F, I introduced a motion to effect more adequate representation of the various societies in the section on the executive committee. This was done at the suggestion of President Essig. It was indicated that for many years the officers of the Section have been selected exclusively from the American Society of Zoologists. This is an important matter in that the President of the Section is a Vice President of the Association.

The motion was promptly seconded and discussed. It was admitted that the implications were correct and that the American Society of Zoologists had furnished the officers since about 1914. The motion was modified to read that the four members of the Executive Committee of Section F consist of representatives of four different societies in the section. The motion was carried unanimously. It appears to be the intention of the present officers to put this change into practice at the earliest possible time.

Recommendations to the A.A.E.E.

From observations and considerations resulting from this and earlier meetings, I wish to make the following recommendations to this association:

1. That especial effort be made to have both entomological societies represented by the full number of delegates allowed who will attend all sessions of the A.A.A.S. Council, the business meetings of Section F, the Union of American Biological Societies and all others which are of interest to entomologists. The delegates should take part in the meetings so that those present receive the impression that the entomologists are active participants. The opinion which now seems to prevail is that the entomologists are only remotely interested and desire no active part. In order to bring this about, I recommend that:
   a. The delegates to the societies mentioned be appointed for terms of three years which will permit them to become acquainted with the delegates from other societies, with the business of the organizations and to hold office. Delegates should be selected on their liklihood of being in regular attendance, and substitutes who will be in attendance should be officially appointed to serve in the place of any delegate who can not attend any meeting,
   b. That a report from the delegates be required and that it be published, at least in abbreviated form, and,
   c. Since delegates to these meetings will be required to miss sessions of the entomological societies, or to go to A.A.A.S. meetings at a time and place where the entomologists are not meeting, that upon written request to the Executive Committee before the meetings they be reimbursed for some portion of the expenses for attending the meetings. This sum may be only five or ten dollars, but it would place the delegates under a greater responsibility to the society than they now feel. This expense sum might well be paid only upon receipt of their written report from the meetings.
2. That the Entomological Societies meet more often with the A.A.A.S. and register at the Association headquarters. The officers of the Association have been aware of the absence of the entomologists. It is urged, therefore, that the tendency for the entomological societies to meet separately be curbed, and that an effort be made to have more of the entomologists register and pay the registration fee to indicate their full cooperation with the Association.
3. That the Entomological Societies urge that a larger number of their members subscribe for at least Section E of Biological Abstracts. Dr. Flynn stated upon inquiry that only a few over 10 entomologists subscribe for the whole or Section E of this important publication. This is not regarded as generous support.

ROGER C. SMITH

REPORT OF THE AMERICAN COMMITTEE ON ENTOMOLOGICAL NOMENCLATURE

In 1941 the Entomological Society of America and the American Association of Economic Entomologists had under consideration several plans for the formation of an American Group to consider problems of entomological nomenclature. At the Annual Meeting of that year, the two societies agreed to sponsor such a group, and the presidents of the two organizations appointed G. F. Ferris and C. F. W. Muesebeck to organize an American Commission on Scientific Nomenclature in Entomology. Fifteen invitations to participate were extended and fourteen members accepted as follows: J. C. Bradley, W. J. Brown, G. F. Ferris, T. H. Hubbell, H. B. Hungerford, E. G. Linsley, C. E. Mickel, C. F. W. Muesebeck, P. W. Oman (Alan Stone serving as an alternate while Oman is in military service), A. G. Richards, Jr., H. H. Ross, C. W. Sabrosky, R. L. Usinger, and G. S. Walley, G. F. Ferris was elected chairman and subsequently, in 1944, E. G. Linsley was elected secretary.

The first business of the Commission was to determine its proper function and methods for procedure. It was agreed that the function of the Commission should be advisory, with the stipulation that this does not preclude cooperation with nomenclatorial groups or committees, nor the initiation or support of petitions to the International Commission on Zoological Nomenclature. The International Code of Zoological Nomenclature and the published Opinions of the International Commission on Zoological Nomenclature were accepted as a basis for consideration of nomenclatural problems. A procedure for operating the Commission was adopted and is now in use, subject to modification as circumstances require.

Nomenclatural questions considered by the Commission include: Fifteen requests for information as to the provisions of the International Code or the application of the Opinions of the International Commission to specific nomenclatural matters (answered directly by the chairman and secretary); an invitation by W. H. Osgood to cooperate with the Emergency Committee on Zoological Nomenclature; a request of C. B. Philip regarding the propriety of considering the decision of the International Commission on Zoological Nomenclature in regard to the name of the Rocky Mountain wood tick; and a question submitted by G. F. Ferris and T. D. A. Cockerell as to whether Articles 35 and 36 of the International Code of Zoological Nomenclature are to be considered as being applicable to secondary homonyms.

Matters under consideration at the present time are: Misidentified Genotypes (submitted by J. McDunnough), The Status of Names Placed upon the "Official List of Generic Names in Zoology" (submitted by R. L. Usinger and C. W. Sobrosky), and The Valid Name of the Dipterous Family Ortalidae *auctt.* (submitted by G. Steyskal).

During the present Annual Meetings the Commission met and took action on a number of points. The following members were in attendance and constituted a majority of the Commission: J. C. Bradley, W. J. Brown, T. H. Hubbell, C. E. Mickel, A. G. Richards, Jr., H. H. Ross, C. W. Sabrosky, and R. L. Usinger. The meeting was held at 9:00 p. m., on December 14, 1944. The following action was taken. H. H. Ross was elected chairman, *pro tem.*, and R. L. Usinger, secretary, *pro tem.* The resignation of G. F. Ferris as chairman and as a member of the Commission was accepted. The resignation of E. G. Linsley as secretary was not accepted. By-laws were proposed for the Commission by J. C. Bradley, and these were carefully considered and accepted as amended. By-laws will be published in the Annals of the Entomological Society of America.

All actions of the Commission thus far have been in accordance with the original mandate set up by the Entomological Society of America and the American Association of Economic Entomologists except for the following points proposed during the present meetings:

(1) It was proposed to change the name of the "American Commission on Scientific Nomenclature n Entomology" to "The American Committee on Entomological Nomenclature." This is in line with the "British Committee" and the "International Committee on Entomological Nomenclature."

(2) It was proposed that members elected by the American Committee on Entomological Nomenclature be subject to confirmation of the Executive Committee of each sponsoring organization.

Respectfully submitted,
R. L. USINGER, *Secretary, pro tem.*

REPORT OF THE COMMITTEE ON COMMON NAMES

A list comprising *51* new common names and *7* changes in approved common names has been processed by the committee in the interim since the last meeting. This list is now ready for submission to the membership.

There is on file with the Chairman of your Committee the beginning for a new list. It should be noted that the most common difficulty in proposals for new common names is omission of reasons as stipulated by our 1939 meeting.

Dr. F. C. Bishopp raised the question whether the number of ballots concerning any name should be reduced from forty as a prerequisite for the consideration of that name for inclusion in the list of approved names. The entire matter was discussed at some length by Peairs, Burgess, Rohwer, Houser, Usinger, Bishopp and others. It was finally decided that the ballot should go to the members as written by the Committee.

JOSEPH WILCOX J. S. HOUSER
E. H. STRICKLAND U. C. LOFTIN
CLAUDE WAKELAND RAY HUTSON, *Chairman*

REPORT OF THE COMMITTEE ON PUBLICATIONS

No report was presented by this Committee but a letter from the Chairman was read by the Secretary in explanation of why no report was forthcoming.

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

SECTION OF EXTENSION

The Section of Extension Entomologists met during the evening of December 14 in the East Room at the Hotel New Yorker. Extension Entomologists from some of the eastern states were present along with visitors; 22 attended the meeting. Interesting discussions were held on cooperation between the Entomologists and Insecticide Dealers, and many had favorable reports to make on the progress of this phase of extension work. Discussions pretaining to the effectiveness of insect pest surveys as conducted by 4-H Club members was discussed, and insect pest survey as conducted by the bureau were given approval by the members. Changes anticipated in post war in Extension Entomology was discussed, and it seemed to be the feeling that the Extension Entomologists will need to expand their services to include urban as well as rural people and place more emphasis on household pest control, insects of ornamentals and those affecting the health of man. An insect exhibit showing victory garden insects was discussed by Mr. W. E. Blauvelt of New York, explaining how this exhibit was used to further the victory garden program in the State of New York. This exhibit was very unique in that it could be packed in a small carton and shipped from point to point. After being exhibited in many counties it showed very little wear and could be used again and again.

Mr. F. GRAY BUTCHER of North Dakota was elected Secretary and J. MYRON MAXWELL of North Carolina was elected chairman for the coming year.

SECTION OF APICULTURE

The section of Apiculture held an evening meeting on December 14, 1944 in the Grand Ballroom, Hotel New Yorker. Chairman J. A. Munro opened the session with an address on the subject "Beekeeping in North Dakota." Following this presentation, two invitational papers were given. They were: "Diseases of Adult Bees" by Dr. E. F. Phillips and "Bee Poisoning" by Dr. J. E. Eckert.

In the business session at the conclusion of this very interesting program, a resolution on the use of insecticides in relation to beekeeping was passed and recommended for consideration by the parent Resolutions Committee. Also officers for the coming year were elected. They were Robert S. Filmer, Chairman and W. A. Price, Secretary.

W. A. PRICE, *Secretary*

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JOURNAL OF ECONOMIC ENTOMOLOGY

Organized 1889; Incorporated December 29, 1913

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